WITH COMPLIMENTS FROM

JAMES H. McCOLL.

AGRICULTURE

AND

IRRIGATION.

INFORMATION COLLECTED BY—

HON. J. H. McCOLL, M.P.

DURING HIS RECENT TRIP THROUGH AMERICA.

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Introduction.

BEFORE leaving for Europe in February, 1905, Mr. Swinburne, the Minister of Agriculture, requested that, while returning through the United States, I would get any information I could *re* water matters and agriculture.

The short time at my disposal prevented me making such a full enquiry as I would have desired, but I tried to use my time to the best advantage, and the following reports embody some of the information I was able to obtain.

There is a magnificent field in the United States for investigation had one the time and means to prosecute it, and the sending of some of our able young engineers to do so would be of great benefit, I believe, to this State.

The Americans are most courteous and obliging, sparing no time or trouble to give an enquiring stranger all the information they can To the many friends who assisted me in my enquiries I return my sincere thanks, especially to Dr. Elwood Mead, Washington, and Professor Fortier, Berkeley. To further particularise where all were so kind would be invidious, so I group all others in my grateful acknodgment. To the proprietors of the *Bendigo Advertiser* for publishing the reports in full and for kindly assistance in issuing them in group form, I desire to express my obligations.

These notes are not intended to teach, but rather to stimulate inquiry on the part of the cultivators in the Northern areas, whom for the past twenty-one years I have represented, and whose friendship and confidence I have enjoyed.

JAMES H. McCOLL,

Quarry Hill, Bendigo, 20th May, 1906.

DRY FARMING.

Report by MR. J. H. M'COLL, M.P.

The term "dry" farming is one often heard in the United States, but in regard to what it denotes, "wet" farming might be a more appropriate phrase. It means successful farming with a limited rainfall and no artificial water supply. To grasp intelligently the varied conditions of agriculture in the United States, an appreciation of the physical character of that country and its topography is required. The area is so vast, and the climatic and physical conditions differ so much, that a reference to that country and its agriculture in a general way may be quite misleading. The United States cover an area 2000 miles broad, and 1600 miles in depth, containing about 3,200,000 square miles. Australia is 2200 miles wide, with a mean depth of about 1100 miles. Its area is about 3,000,000 square miles. From the east of the United States to the Missouri or the 97th meridian, about one-half the area of the States, there is a mean rainfall of about 40in. per annum. Then the arid belt is struck, running west some 550 miles by about 1100 miles north and south, an area of nearly half a million square miles. Then for 1000 miles to the west coast intervene the Rockies, beyond them a semi-arid region, and next the Sierras near the coast. The great central arid area stretches from the Canadian boundary to Mexico, and includes parts of North and South Dakota, Nebraska, Kansas, and Texas, and east part of Colorado, or about one-seventh of the United States, with an average rainfall of about 12in. Lured by an occasional season of good rainfall, much of this land has been occupied by settlers several times, all in their turn driven away by the fatal recurring seasons of drought. Women go mad in it, and men, battling as long as it is possible, at last leave broken in heart, body and pocket, their physical and mental energy gone, wrecks whom no one will employ, useless cumberers of the ground. Land forfeited is again taken up by railroad companies and speculators, and they, on a rainfall again recurring, tempt settlers, who, fondly hoping the days of drought are past, court ruin, and find it, as their predecessors have done. The desire for land is so great, and it is so difficult to get, that men take the risk. How like is this to our Australian experience, and how often have we seen it here, and not so long ago.

For some years past the attention of the Federal and State Governments has been given to this country and its failures, and inquiry has been made, and methods tried to cope with the drought, and render settlement less precarious. Attempts are being made to store water in wet seasons, and give settlers enough to irrigate four or five acres of land, and so enable him to grow shade trees, vegetables, fruit and fodder for horses and cows. Attention was also given to the character of the seed used, and importations were made, first in 1900, of tried drought-resisting wheat, oats, rye, and millet from Siberia, Southern Russia, and Algeria. Experiments have also been made by varying the system of tillage, to make more use of the scanty rainfall, by conserving it in the ground, storing it up for use by capillary attraction when needed for plant growth. At the State Experiment stations, trials have and are now being made to grow not only several crops, but fruits and vegetables with a rainfall of 12 inches or less; but before these attempts were made others were at work on the same problem, and it is now claimed they have succeeded. The foremost investigator in this line has been Professor H. W. Campbell, of Lincoln, Nebraska, who for 20 years has been patiently testing various methods, and claims an absolute success. I was unable, owing to distance and the shortness of time, to visit him, but wrote to him, and in his reply he writes as follows:—"That I have reached a high degree of success in devising and outlining ways and

methods for successfully guarding against the ill-effects of drought and for increasing the quantity, quality, and certainty of all crops is evidenced by the marvellous results already obtained, and the intense interest manifested by those who have investigated and know most about it." He has issued a book called the "Campbell Soil Culture Manual," explaining his methods of tillage. I endeavored to get this, but the booksellers had sold out, and two copies I ordered did not reach me before I left San Francisco, but should be here shortly.

In the north-west, Dr. Cook, of Portland, Oregon, who has been cattle ranching, has for 15 years been also experimenting in cultivation with light rainfall, and has been for some time engaged by one of the public bodies of Oregon to lecture on the subject. I was fortunate enough to meet him, and he spoke quite triumphantly of the victory over drought by the use of new methods of tillage. He assured me that with a 12 inch rainfall a good crop could be assured. He was, he said, disposing of his estate, and was preaching the gospel of "Dry Farming" more from a desire to benefit the cultivators than from any desire of gain. I believe a very slight inducement would cause him to visit Australia and pursue the subject here. So far as I could gather, he was working on similar lines to Professor Campbell, though unknown to each other, and he showed me documents leaving no possibility of doubt that he had the confidence of some of the best men in Oregon, under whose auspices he was prosecuting the work. Professor Campbell's, as well as Dr. Cook's, system demands deep ploughing, thorough pulverising, and packing the soil at the bottom. For the latter there is an implement made called a "subsoil packer." The object is to save the natural moisture and make a storage reservoir in the soil instead of on the surface, and he has not merely solved the difficulty theoretically, but has in numerous instances practically demonstrated it successfully. Like most problems, the elements are very simple, and the solution was wrought out by careful and minute observation of facts which have been known for ages, but the lessons they have taught have been unheeded, or regarded as of no importance.

In a dry country like ours the soil is robbed of its moisture by evaporation, the moisture creeping to the surface by capillary attraction, and escaping into the atmosphere, leaving the soil dry. Any object, a log or stone, or bushes will check this evaporation, and assist in retaining moisture in the soil. Rainfall beats the surface close, preventing penetration, and causing the moisture to run off. Later the heat cracks the ground, facilitating the escape of the moisture therein, and the solidifying of the ground accelerates capillary attraction. What has to be done is to secure the penetration into the ground of all the moisture that is precipitated, and having got it there to lock it up till required for stimulating plant life.

Not having Professor Campbell's manual yet, I cannot quote from it, but hope to do so later on. Those interested can obtain it from the address I have given, the cost being half a dollar and postage. Experiments are being made at several of the experimental stations, and the importance of the question is shown by the fact that the following railroad companies are subsidising the cost of the experiments:—Great Northern, Northern Pacific, Union Pacific, Chicago, Burlington and Quincy, Colorado and Southern, Chicago, Rock Island, and Pacific, Chicago, Milwaukie and St. Paul. The matter of thus assisting farmers might well be made a greater feature of Australian railway management than it is. In some places similar crops are being planted in adjoining areas, and ploughing to the depth of 14, eight and six inches deep, is performed, and the results watched. At the experimental station, Cheyenne, Wyoming, which I visited, some interesting experiments are being carried on. Mr. Herrmann, the director, was away, but Mr. D. G. Rasbacher, his assistant, kindly drove me out to the farm, some three miles from the town. It is under the control of Mr. J. H. Gordon, a successful practical farmer, who has lived in the semi-arid west for 35 years. He is a cousin of the late Rev. D. Gordon, of Brighton, and left Belfast, Ireland, for the United States when a youth. The farm contains 70 acres, and 27 acres are being devoted to competitive experiments by irrigation, also the ordinary and the "dry" farm methods. The irrigation is provided from a well, the pump being worked by a double windmill, the wheels working reverse ways, the only one I have seen. There are 10 plots, of half an acre each, ploughed eight inches deep, and subsoiled. These will be irrigated, and were to be sown with Durum wheat, potatoes, field peas, sugar beets, corn (maize), East Oregon alfalfa, Brome grass, beardless barley, rye, and oats.

The plots to be cultivated in the ordinary way were each one acre in extent, and to be sown with the same seed as the other plots. The plots to be cultivated by the "dry" farming method, constant cultivation, were half an acre each in extent, and sown with the same seeds as the rest. These will therefore be tests under irrigation, also by ordinary farming, and by constant cultivation, and the results are to be sent out to

me. The annual average rainfall here is 13 inches. The ground is a light friable soil, containing a good deal of gravel, and similar to most of the Prairie country round about. This experiment is being carried on under the supervision of a committee of whch Mr. C. T. Johnston, State engineer, is the chairman, and 5000 dollars have been given to cover the cost, the contributories being the United States Department of Agriculture, the Union Pacific, Burlington, and Colorado and Southern railways, the State Agricultural College and the State of Wyoming. The experiment will be carefully carried out and keenly watched, and the results must be of great interest to those who live in semi-arid regions.

That the Campbell method of soil culture is attracting attention was very obvious, as in the Agricultural Bureau at Washington, in the irrigation, cereal and power branches, the officials all talked of it, and at most of the places in the west it was a leading topic. Some there were who affected to treat it lightly, saying "Oh, we knew all about this long ago; everyone knows if you till fine and deep you will get better crops, but as in the case of many other well-known facts, they pass unheeded till some inquiring mind grasps them, and shows their potency and value

This system of soil culture does not only mean storing the moisture in the ground, but it explains the principle of the movement of moisture so that plant food for the crops may be obtained by following a scientific system of cultivation, thus controlling conditions, and eliminating the element of chance in large measure. The trouble in our northern country has been, not so much the want of rain, but the evaporation caused by the sun's heat and hot winds, and the fact that the rain does not always come when the plants need it.

Professor Campbell, in an address to the Colorado State Realty Association towards the end of 1901, says:—"By a careful study of the available works as brought out and compiled by scientific research in the past, coupled with over 25 years of observation and practical experiments with the soils of the more arid portions of the Dakotas, Nebraska, Kansas, and Colorado, we have been able to prove beyond question of doubt by practical tests and results that nature has provided every necessary means for transfering these bleak prairies into a verdant garden of plenty." After explaining the physical or mechanical condition of the soil, he goes on to say:—"We come to the all-important question—our supply of moisture. Repeated experiments by many scientific investigators have shown that seven inches of water, if all utilised, will grow a good crop, mind you, a good crop—of any kind of grain. Here we have 14 inches annually. Our plan under these conditions is to get our seven inches of necessary water from two years of rainfall, or from 28 to 32 inches of water. How? By storing one year's rainfall in the soil by a system of summer culture, carry it through the winter as a reserve to start our crop with in the spring, as well as to carry us through the periods when we cannot get the needed rains while the crop is growing."

"The statement that we can store the greater part of the season's rainfall (come when it may) in the soil, and hold it on through another year, is what staggers most men who have not seen it done. But we can do it; you can do it."

In his closing remarks he says:—"There is no patent in the process to be sold out by counties. There are no proposed secrets. There is no monopoly. The whole question is one of education. It is a broad, deep subject. For 14 years we have been steadily working it out, and every year tells us something more. The most gratifying feature is that every new development points to even greater possibilities, and my greatest ambition to-day is that I may be spared just a few years longer, and again have the privilege of meeting you, for I shall so delight in telling you, 'I told you so.'"

Instances can be given of results obtained, but space will not permit it at present.

I saw in Denver wheat and oats of the finest character grown, I was assured, under a light rainfall, and by the Campbell system. If this can be done, what is it not possible to do if we can turn the surplus winter waters of the Goulburn and our other rivers on to the parched land of the West, and storing it there with such rainfall as we have, utilise it for the yielding of certain harvests, where under present conditions farming results are no more secure than the cast of a gambler's die? The matter of the drought-resisting cereals, sorghum, millet and grasses, I must leave for another paper.

Drought Resistant Farm Crops.

"In the United States of America the demand for land by intending settlers for many years past has been very great. The greater part of the good land there, as in Australia, was prodigally squandered in the early days, and attention had to be turned to the enormous semi-arid areas. With the methods of farming then employed, and the cultivation of the kinds of crops grown in more humid regions, the attempts at settlement ended in failure. It was decided to change the varieties of seeds, and procure from countries similar in climate and physical conditions the seeds successfully grown there. Importations were made from the dry sections of Russia, Siberia and Algiers, of wheat, oats, sorghums and grasses, and these have been successfully cultivated. I was informed by Professor Carlton, the head of the cereal branch of the Bureau of Agriculture at Washington, that by the use of the imported seed the wheat-growing area has been extended two hundred miles further west. The wheats are called macaroni wheats, as they are used in the making of that food. The first trial was made in 1900, and so rapidly has its cultivation progressed that a yield of ten million bushels was anticipated this year. It is also called Durum wheat, because of its hardness. It comes from Russia, where it is grown on the great steppes and semi-arid plains of the Volga River. It is said to grow in the West with a 10in. rainfall, and yields 8 to 10 bushels per acre with ordinary farming, while with better cultivation under the Campbell system it will yield over 30 bushels per acre. It is a hard wheat, creamy in color, with more gluten in it than the ordinary wheat. It retains moisture in bread longer than ordinary wheat, and will keep it six or seven days sweet and moist.

"At first the millers had a prejudice against it, as it was hard, and took more time and power to work than the ordinary wheat. This feeling has now died out, and the wheat readily commands the market price. It is said to yield in the dry districts 25 to 100 per cent. larger crops than the ordinary wheats. It is grown with a rotation of oats, corn (maize) and barley, and does best when stubbled in on corn land by the disk. After two seasons of wheat, then rotate the crop. The Department of Agriculture urges its cultivation. The varieties grown are Black Don, Yellow Gharnovka and Kubanka. The lastnamed is said to be the best. There are also some Algerian wheats, said to be successfully grown, called Pelissier and Richi, of which the former is highly spoken of. The ordinary wheats grown, which, however, do not yield so well as the macaroni wheats, are Blue Stems and Fyfe. These are considered the best of the ordinary wheats for the dry country.

"Of oats, the Swedish Select is said to be the best so far as regards the yield, but it is not recommended to put in too much. The sixty-day oat is early and good, ripens quickly, and escapes rust if the season is wet. It holds the grain, and stands up better than the Swedish Select, but does not yield so well. The Texas Rustproof is also a good oat. There is a kind of wheat like a barley, called 'Emmer'; it is not good for milling, but is very good for feed. Two kinds of barley—a two row and a six row—were also spoken of as being drought resistant. There is a broomcorn millet called Proso, which yields a large amount of hay, and also 25 to 30 bushels of seed per acre. It is good for feeding hogs or sheep, and the seed is the best feed for poultry. It gives good crops in dry seasons.

"A dwarf milo maize is grown reported to yield 40 to 60 bushels per acre, and two crops per year. It equals corn (maize) for feeding purposes, and is considered a highly valuable crop, yielding a great profit under the Campbell system of culture. There is a Mexican corn, a flint variety,

rich in protein, which produces good fodder, and always some corn.

"The sorghums are also said to make a paying crop in Eastern and North-eastern Colorado, but do not ripen seed well. They are saccharine, and non-saccharine; of the sweet, the best for quality, quantity and producing seed is Early Amber. Early Orange and Kansas Orange yield well, and are of good quality, but give little seed. Of the non-saccharine varieties, the Red and White Kaffir corn are of good quality, and yield fairly, but give little seed. Jerusalem and Brown Durra give abundant seed. but are small and poor in quality. The yellow and white milo maize are poor in seed, but of good quality, and yield a medium quantity. In Central and Eastern Kansas and parts of Nebraska, Oklahoma and Texas, alfalfa (lucerne) is said to do well and resist drought fairly. Austrian brome grass is also strongly recommended, and can be cut for hay or seeded down for pasture. If cultivated for seed, it will yield 150 to 500 tons per acre.

"I inquired as to where the drought-resistant wheat and oats could be got, and Professor J. H. Shepherd, of North Dakota Agricultural College, replied that the superintendent of the Edgeley Sub-station could supply a limited quantity of macaroni wheat at a dollar and a quarter per bushel. Emmer and Sixty-day oats, which Professor Shepherd recommended, could be supplied at one dollar per bushel. I do not know the value of the other seeds.

"Secretary Wilson, of the Bureau of Agriculture, Washington, will no doubt be glad to arrange for a shipment for trial, but no time should be lost in applying, as there is a good demand for drought-resisting seed.

"There will likely be other varieties which might be sent, and instructions as to treatment should also be obtained. I see no reason why the success that has followed the cultivation of these drought-resistant crops in the semi-arid districts of the United States should not also be obtained in similar country in Australia."

Inoculating the Soil.

With Nitrogen-Fixing Bacteria.

Sir, I was requested by several friends to make some inquiry while in America into this matter with a view of increasing the production of our soils in the north, and though not able to persue the inquiry to any great extent, now submit such information as I obtained. The importance of nitrogen in the produceion of plant life (from which all animal life is sustained) is paramount, and any process that will repair and return the loss of nitrogen continually going on becomes of the very first importance.

The wonderful part that bacteria plays in creation is well known, and of all these minute, yet mighty organisms, the work of the nitrogen-fixing bacteria is the most important, and the most beneficent. Their work absorbs from the atmosphere and returns to the soil the most essential element of plant life, and too much attention, both from scientists and practical men, cannot be given to the problem of maintaining the supply of nitrogen, and thus retain the fertility of our soils. I do not propose to write a treatise on the subject—that is beyond me—but merely to relate the information I gained recently in United States. The question of supplying the soil with nitrogen by its inoculation with nitrogen-fixing bacteria through leguminous plants, is but of recent origin, and the first distribution of cultures, I believe, by the Department of Agriculture, in America was in 1904. To prevent any monopoly of the manufactures of these cultures, the department secured the patent, and Dr. George T. Moore developed and perfected the method of their production This distribution seems to have been successful, for the demand made on the department for inoculation material last spring was very large, and the supply was early exhausted, A furteer distribution was made in the fall of the year, and more will be distributed next spring. In application for future distribution the applicants are repuested to state what legume is to be sown, the time of sowing. and quantity of land to be treated. The department furnishes to all applicants the necessary information, and as far as possible, starting, or foundation cultures to bacteriologists of experimental stations, and commercial concerns properly equipped for carrying out the industry, but gives no guarantee of their value. The understanding is that any cultures furnished are to be treated according to the directions laid down by the department Applicants are requested to thoroughly study the soil conditions where it is proposed to use the cultures

I think the bulk of the cultures obtained must have gone to the humid States, for my inquiries showed that in the West many did not know of them, and but few had tried them, though where tried the results were successful. So far as I could learn, the methods had been practiced in the West in the following places :—In Texas, some experiments have been tried with marked results : also in Montebello, Los Angelos, in Cheyenne, with success in gardens, and in Modesta, with good results. In some places the experiments had just begun, and no results are yet forthcoming, and in other places it was said they were not needed. Out of about 40 replies received, only five places had results, but these were favourable and the rest were either waiting results or had not tried the system. The replies came from nearly all the States west of the Missouri.

The great demand made on the Department of Agriculture shows that in many places the experiments must have been successful, and the fol'owing information, abbreviated from a bulletin issued by the department in May last, may be of interest :—It states that inoculation is necessary for soil low in organic matter, where leguminous crops have not previously been grown, or if the legumes grown were devoid of nodules, or "nitrogen knots," showing the need of nodule-forming bacteria; or when

the legume sown belongs to a species different to those previously sown in the same soil.

Innoculation may prove advantageous when the growth of legumes is sickly; even if the roots show some nodules, a more vigorous growth will often result, or when a leguminous crop already sown shows signs of failing, due to the absence of root nodules Inoculation is not required where the leguminous crops are up to the average, and roots show nodules in normal quantity. The cultures of nitrogen-fixing bacteria are not fertilisers, nor do they contain nitrogen, but the bacteria aids the legumes to secure nitrogen from the air through the formation nodules. If the soil is already rich in nitrogen, they are not needed.

Failure may be expected in soil that is acid and in need of lime. Lime is needed to correct acidity, and also for the proper activity of the bacteria, as well as for the growth of the plants, where the soil responds in a marked way to fertilisers, such as potash, phospheric acid, or lime. The activity of the bacteria in securing nitrogen from the air, and rendering it available to the legumes, does not do away with the need of fertilising elements like potash and phosphorus, Inoculation will not overcome results due to adverse weather or climate bad seed or improper cultivation. Directions must be carefully studied and intelligently followed. The value of pure-bred bacteria cannot be predicted in any soil without trial. The department, however, anticipates that, unlike fertilisers, bacteria will in time be cheap enough for each farmer to try in each leguminous crop he may have. The method of distributing in dried form, and the easy methods of multiplying on the farm in sufficient quantities to inoculate fields, will make it possible to have all fields inoculated at all times.

The Cost of the Cultures.

This cannot be yet estimated, as the expense of running a commercial concern, with all the various changes, cannot be compared with the expense of a department, and makes comparison difficult or impossible. Natural competition, it is anticipated, will shortly reduce the present values, and the wisdom of the department securing the patent has already been demonstrated.

Increasing Cultures.

Many inquiries come as to the production of a large quantity of liquid culture from the dry culture secured for a start, that is, how to make an acre culture do for 25 or 100 acres. These methods only yield good results when special precautions are taken, and are not generally recommended. Contaminations such as yeasts, molds, etc., are apt to take possession of the culture solution in which the bacteria are being multiplied, and unless great care is used in sterilising *all* utensils, failure may result. The time required to reproduce a large quantity of bacteria from a small one makes the risk of contamination greater than where the dry culture is proportioned to the amount of the solution.

Preparing and Using the Solution.

Directions to make ten gallons of liquid culture, sufficient to inoculate 20 bushels of seed, are given, and by computation may be adopted to five gallons or intermediate quantities. To prepare the culture solution, first select the tub, bucket or other vessel in which to grow the bacteria. Clean and scald it out thoroughly. Good drinking water will answer, but rain water boiled and allowed to cool is best. Add to 10 gallons of water 12ozs. of brown or granulated sugar (preferably granulated), 1¼oz. of potassium phosphate (monobasic), and 1-16 of an oz. (30 grains) of magnesium sulphate. Stir until dissolved, then drop the bacteria-laden cotton in the solution. Cover the tub with a moist, clean cloth. Keep warm, but not above blood heat. After 24 hours add 6ozs of ammonium phosphate and allow the mixture to stand for 24 hours. The liquid should now be cloudy and ready to use. If not cloudy allow further time.

To Inoculate Seed.

Moisten seed thoroughly, using about half a gallon per bushel. It may be done in a tub or trough or on a clean floor. After inoculation spread out in a clean shady place, till dry enough to handle. If not to be used at once, the seed must be thoroughly dried, to prevent moulding. The inoculated seed if thoroughly dried may be kept without deterioration for several months.

To Inoculate Soil.

Take enough dry earth or sand so that the solution will merely moisten it. Get soil from the field to be inoculated, to prevent spreading diseases or weeds. Mix thoroughly, so that all the particles are moistened. Thoroughly mix this earth with four or five times as much. Spread the inoculated soil thinly and evenly over the prepared ground, as if spreading fertilizer, and harrow in immediately, to protect the bacteria from sunlight. In using this method allow one gallon of the liquid culture to four acres or less.

Keeping Cultures for Future Use,

The question is asked as to the farmer keeping culture over from one year to another by soaking some liquid culture in cotton, and drying it. This practice is strongly condemned, as contaminations take place and spread so readily that results can only be expected by starting with a pure culture prepared by a trained bacteriologist in the laboratory. These cultures will keep from six months to a year. Liquid cultures, it kept lose in effectiveness. Any large investment is deprecated without previously experimenting in a small way.

Danger of Inoculating by Soil Transfer.

In some cases this has proved successful, but the danger of transferring diseases, which is readily done, in the soil, is so great that it is not adviseable Animal and plant parasites live in the soil for years, and are readily transmitted, and might become a serious menace if transferred to clean localities. Several cases have been reported to the department, which warns farmers against such haphazard methods.

Pure Culture Inoculation.

The extensive experiments carried on by the department in 1904 have demonstrated that by the proper use of pure cultures the nodule bacteria are carried into the soil, in such a way as to form root nodules, and brought about the growth of each legume in soils where it had previously failed from lack of bacteria

The Department of Agriculture is developing types of the bacteria associated with leguminous plants which will have greater activity, collecting from the air more nitrogen per acre than forms now common in nature or available from laboratories. Further investigations are being made, but the large demand for cultures for leguminous crops has taken up much time, and seriously retarded these inquiries. The limited area of our Victorian soils and the waste of productive power going on makes this subject one of great importance, and worthy of the most careful inquiries and investigations of our department here. It is fortunate in having as Director Dr. Cherry, who is so well qualified to instruct in this branch of science, and the United States department, if referred to will always forward the latest results obtained there.

It is noticeable that in some replies to my inquiries it was stated that these cultures were not needed, as the land could always be brough back to fertility by laying it down in alfalfa after cropping with other plants for a few years. This, I was frequently informed at Greeley, after four or five years cropping with wheat sugar beet, or potatoes, they sow alfalfa and feed it down for three or four years, when the land recovers its lost nitrogen, and is fit for any crop again. But little manure or fertilizers were used, the above being the universal practice.

Dry Farming.

(FURTHER REPORT).

I lately sent a report on "Dry Farming," the reprint of which has caused some interest to be taken in that subject. Since doing so, the "Soil Culture Manual" of Professor Campbell, of Lincoln, Nebraska, has come to hand, and I propose to give a digest of its main features, in the hope that it will lead to further inquiry and experiment on the lines on which Mr. Campbell works. Those interested should, however, obtain the manual itself, as it is only possible to indicate in bare outline the matter of a volume of 95 pages in a brief report. The perusal of the manual excites a keen interest in the subject, and impresses one with the great importance its teachings have for those who are so strenuously battling to develope the drier areas of this great continent.

Preliminary.

Three years ago Mr. Campbell's first manual was prepared, in which he stated "the yields of the cultivated areas in the semi-arid belt were not one-half what they should be."

The additional experience and observation since gained lead him to state in this year's manual, without hesitation, "that the average yield of the Western Prairies is not one-fourth of what it might be if our farmers would only grasp the principles involved in properly handling the soil and its relation to the plant, including the part that water, air, heat, and light play separately and collectively in the growth and development of all plants; also how these elements are regulated by the physical condition of the soil, and the methods by which these proper physical conditions may be secured and retained through a simple system of cultivation." The manual, it is stated, does not "lay down a code of imperative rules to govern the farmer in every act of soil culture, but by explanatory illustrations presents as clearly as possible the fundamental principles which govern the movement of moistrue in the soil, the development of plant life, and the quantity and quality of the crop. In the great semi-arid area a general rule may be applied, and if followed diligently, the resulting storage and conservation of the natural rainfall in the soil, together with careful preparation and such after cultivation as shall admit of the proper quantities of air, will produce in average years as good crops of cereals and all of the vegetables that are commonly grown, as can be produced in the humid central portions of the United States. Storage and conservation of the rain waters, and a careful observation of the necessary physical condition of the soil, is the basis of all this fruitful production."

The Object Aimed At.

This is the profitable production of grain, trees and vegetables, in regions known as semi-arid, where the annual rainfall will average from 12 to 14 inches, and where the soil is of such a character that only the proper application of moisture and cultivation is required to cause it to be fruitful.

The Factors Necessary for the Attainment of This Object.

The main factors are the storage and conservation of the natural rainfall in the soil, and a careful observation of the necessary physical conditions of the soil in the seed and root bed. By physical condition is meant the proper preparation or condition of the soil that will produce the best possible crop results, the processes of tillage to secure abundant yields.

Mr. Campbell states his wish is "to prove that nature has provided all necessary elements on these broad level prairies of the semi-arid belt to grow cereals, vegetables, forage, and fruit, in such quantities and of such quality to make the most sanguine minds marvel. To do this the tiller must learn what to do, when to do it, how to do it, and why he works the soil by this method, which enables nature to reveal all the possibilities she stores in this workshop for an unlimited supply of crop material. It does not require a vast amount of hard and expensive labor to get large results, but it does require effort, with knowledge and judgment."

The factors are cultivation, to induce percolation of moisture, the retention of such

moisture in the soil by the checking of evaporation, the proper making of a seed and root bed. When moisture leaves the soil it becomes dead.

"To secure the best possible physical conditions, the greatest care should be exercised to do the ploughing, packing and cultivation while the soil is moist. When the soil is moist, as all observing farmers know, the soil grains more readily separate one from the other. The real object of ploughing is not simply to turn the soil over, but in addition to turning the soil over is the pulverising. The more thoroughly this is done the better opportunity the heat, air and moisture have to combine all the properties into plant foods, so that they may be assimilated by the plant."

The Way the Factors are Manipulated.

The Disc Harrow.

Mr. Campbell's first reference to implements is to the disc harrow, in a chapter on its use and abuse. It is, he says, the most important implement to the Western farmer, but from its conception its usefulness has been more or less misunderstood. Thousands of acres have been put in by it, resulting in total loss of labor and seed. The great value of the disc harrow "lies in its adaptability to the protection of moisture, the preparation of the surface soil for the encouragement of rapid percolation of the rain water, and in thoroughly pulverising a somewhat cloddy ploughed field, and getting an improved physical or mechanical condition of the soil. It has been used on thousands of acres instead of ploughing, when it should have been used to precede the plough."

Instances are quoted where its use for preventing evaporation and preparing the surface to receive moisture has increased the yield of corn (maize) 20 bushels per acre. He strongly urges its use early in the spring in all stubble ground. "For best results double-disc the ground by lapping one half, the object being to thoroughly pulverise and loosen the surface for a two-fold purpose. To loosen the surface and form a soil mulch to prevent the loss of moisture by evaporation, as well as to break the hard, crusted surface, to promote a more rapid and complete percolation or soaking into the soil below of the early spring rains, and it is of equal value to use immediately after the small grain or any other crop is removed. It is advised whenever possible to fallow behind the harvester, and not allow the soil to be exposed a single day to the suns rays after the crop is gathered."

He says it is difficult to explain in strong enough terms the full force and meaning of this, and gives the reasons, which, abbreviated, are as follow:—

First.—There is no time in the year when water, held in the soil near the surface in sufficient quantities, will bring about so many valuable chemical changes as during the months of July and August. (Here January and February). And these changes mean additional bushels to the next crop. But they will not take place unless the surface is loose and the soil is moist.

Second.—If there is any moisture in the soil below, by preparing this fine mulch of a liberal thickness this moisture will accumulate in the firm soil just beneath. If no more rains come, the ground is in perfect condition to plough, because of this moisture.

Third.—If no ploughing is to be done in the fall, this moisture can be carried over till next spring, when in case of a dry spring the soil, if properly handled, can be planted, and the seed will immediately germinate and grow, while your neighbor is worrying about a dry country.

Fourth.—If you wish to fall-plough for spring crops. If the soil is dry it is folly to plough, but if the moisture is held it is wise, provided the plough is followed by the sub-surface packer, firming the lower portion of the furrow slice while the soil is still moist, holding the moisture below instead of allowing the furrow to dry out, as it will if left loose by the plough.

Fifth.—If fall wheat is to be sown, this early discing may mean 10 to 20 bushels more per acre. If the moisture is held, any subsequent rain will percolate deeper and quicker. If the rain be heavy, so as to pack the surface, use the harrow thoroughly as soon as possible. Then you are ready to plough for fall wheat; the soil is moist. Follow the plough with the packer, and the packer with the Acme harrow. There will be a firm moist seed bed, the wheat will come up stout and grow rapidly, and there will be no fear of winter killing.

Mr. Campbell deprecates using large discs, and strongly prefers a disc of 14in. diameter, because of its increased pulverising effect. He advises:—

"Don't buy a disc too large in diameter Always double-disc by lapping one half."

This leaves the surface level if you drive so the outside disc will just fill the furrow left by the centre of the disc just preceding "Keep the disc sharp. It pays. Buy as broad a disc as you have horses to draw it. Time is money. Always precede your ploughing by thoroughly discing. It helps materially in obtaining a fine, firm root bed."

Cross-discing is not approved, as it leaves the surface uneven, and assists evaporation.

So much stress is laid by Mr. Campbell in discing that I have quoted so fully from his remarks on it.

Ploughing.

In the chapter on ploughing, a cross-section of furrows ploughed in the ordinary way is given, showing a cavity under the furrow, and the stubble and weeds lying against the next furrow from the bottom to the surface, these conveying the moisture away, and assisting evaporation. If the ploughing be shallow, the harrow will work the ground fairly down, but if six or more inches deep the cavities will remain, and have a serious effect. They cut off the seed or root bed from the subsoil, preventing the movement of moisture upward. It forms air spaces, which aid in drying out the adjacent soil. It also prevents the lateral roots or feeders from permeating this portion of the soil, and generally prejudices the growing crop. Had this land been double-disced before ploughing, the stubble, weeds or manure would have been scattered through the lower part of the furrow, and the soil would have been finer.

After the ploughing the sub-packer is used. This implement has 10 wedge faced wheels, which have both a downward and lateral pressure on the soil in the spaces between them, and the use of this implement leaves a firm and evenly-packed stratum at the lower part of the furrow. After the packer has been used, the ordinary smoothing harrow, or the Acme harrow, if employed, will pulverise and make firm the surface. This also makes firm the part under the surface, giving a perfect seed bed, while the portion packed underneath forms the main root bed.

Mr. Campbell presses the importance of attaining such a physical condition of the soil favorable to holding the largest amount of moisture to the square inch to the rapid movement of moisture by capillary attraction, and to the prolific growth and development of the lateral roots with their thousands of little feeders. This, he says, cannot be obtained without thoroughly ploughing, pulverising, and packing the soil every year. Water is held not in spaces, but in the forms of films or coverings around each diminutive soil particle, consequently the greater number of small particles of soil the greater the amount of water held. Professor Campbell gives two illustrations to show this. If a cube 1in. square be cut into eight squares, the surface area is increased from six to twelve square inches, and further cutting will increase it still more. Take a pound of coarse buckshot and put it in one glass, and a pound of the very finest bird shot in another. Then measure carefully an ounce of water into each glass, shake it well, so that the shot moistened all over; then tip the water out, and measure it, and it will be found the fine shot has retained nearly 13 times as much water as the coarse shot, so it is with coarse and small particles in the soil.

The depth of ploughing must be governed by the condition of the soil, the time of the year the ploughing is done, and the time it is to be seeded or planted, also the tools available. For average prairie soil plough fully 7in. deep, if it is to be seeded soon after. The soil must be moist, and not wet. The surface must be disced before ploughing, and the sub-surface packer follow close to the plough. The ploughing done before noon should be packed before going to dinner, and that done in the afternoon before leaving the field at night. The Acme harrow should then follow to get the surface in good condition before the clods get too dry. If the farmer has no packer, then plough 5in deep, and use the common harrow with teeth slightly slanting, and weighted, the object being to pulverise and firm the under portion of the furrow." These observations are very important.

Breaking New Prairie Lands.,

"Use the regular breaking plough, cutting about 2in. deep. It is best to break as shallow as it may be possible, in order to turn the sod completely over, and have it hold together. It should be done as soon as the grass begins to grow rapidly in the spring, turning it as flat as possible. Roll it to make it lie firmly against the subsoil. Follow with the Acme or common harrow, going over a sufficient number of times to loosen the soil from the sod, in order to fill all cracks and crevices with loose earth to form a perfect blanket. This will prevent the loss of moisture, holding it as far as it may be possible beneath the blanket, and in case of heavy rain it will be well to harrow again. With this blanket properly provided during June and July (here December and January), the sod itself will not only be found to be well rotted, but the top of the subsoil to a depth of 1 to 3in. also.

In August (here February) or as soon as the soil beneath the blanket is rotted, it should be ploughed again, this time with the stirring or stubble plough, cutting about 2½in. deeper, and following with the sub-surface packer, the same as outlined for ordinary stubble ploughing. The harrowing should be very thorough. If care be

taken to conserve the rain waters, and the work well done, the ground may be planted to fall wheat, or spring crops, the following spring. There is no economy, but great waste, in trying to economise or minimise the amount of labor required to thoroughly prepare the soil for the sowing or planting of grain. for the work of thorough preparation is easily and quickly done, and when once done a successful harvest is assured. A very interesting chapter on

Sub-surface Packing

is given with illustrations, showing the growth of plants in packed and unpacked soil; also the rapid germination in packed soil. Among other instances is the following:—On Kilpatrick Bros.' ranch, in Chase County, Nebraska, where Mr. Campbell had directed operations for fall wheat in 1903, the wheat was sown 14th September, and in four days the field could be discerned green from the town of Champion, two and a half miles away. In the locality hundreds of acres were sown, but not one showed green that season. From 10th September no rain fell for seven months, and the Kilpatrick wheat, yielding over 30 bushels to the acre, was all that was harvested in the country, the rest being a total failure. The chapter winds up by restating "that the process of packing the under portion of furrow or ploughed land creates three conditions to aid in carrying the growing crop over long dry periods, namely:—

"(1) More water in the soil; (2) a stronger capillary movement of water; (3) more prolific growth of roots.

"Don't pack the surface; it increases the loss of moisture by evaporation. Less seed is needed in packed soil than in loose soil for the same crop result. Pack the lower portion of your ploughing the same day you plough, to save the moisture."

Summer Culture.

Summer fallow practised in the East was tried in the semi-arid region, but the results were not encouraging, and it gave place to summer culture with marked success. The work is begun as early in the spring as possible, with the disc harrow. If rain comes a second discing is needed. The surface must not become crusted, nor must weeds be allowed to grow. Plough in June or early July (here December or January), and pack the same day, following it with the Acme harrow, going over the entire day's ploughing. In case of extreme heat more cultivation is necessary. Watch the firm soil just below the mulch; if it is moist it is all right; if it shows dry, cultivate again. The chapter on summer culture is most interesting, but can only be alluded to. The following passages are extracted:—"Remember it is not the object of summer culture to give the land a rest, but rather the reverse. The object is to keep the land alive and actively engaged in the manufacture of plant foods, and to improve the physical condition of the soil by every part of the work done, either directly or indirectly." The following passage reads somewhat strangely to us:—"It is altogether too common an idea that the quantity and quality of the crop depends upon climatic conditions. This does not apply to the semi-arid belt. The success of the farmer depends in a great measure upon the quantity and quality of the grains and vegetables he raises. Under the ordinary plan of farming the expense of preparing, planting and cultivating is just the same whether we get 50 bushels of corn or five bushels, or none at all. If we proceed properly, the necessary labor may be 50 per cent. more, but even if it were double, and we succeed in getting 30 or 40 bushels of wheat in season, when our neighbors under ordinary conditions get five or 10, does it pay? If we are able to get 80 bushels of corn when our neighbor gets 30, does it pay? At Pomeroy model farm, Kansas, with summer culture in four successive years, 1901 to 1904, the wheat cropped 40 bushels per acre, while the yield in the same locality for the same years averaged less than 10 bushels. Three other fields in western Kansas and Nebraska are authentically reported in 1904 in localities remote from each other, each summer tilled, cropped 31, 36½, and 41 bushels respectively an acre, while fields in the same locality planted by the common method were from 60 to 90 per cent. total failure, and the best yields did not exceed one-fourth of the above quantity." A number of other similar results are given, the result of carrying over in the soil the rainfall of 1903 to the dry season of 1904. The chapter ends with the following:—"Summer culture for the storing of the rain waters in the soil, although comparatively new as outlined, is a most important adjunct to farming in the West. Begin your summer culture as early in the spring as the conditions will let you on the ground with your disc harrow. Don't let the weeds grow, thinking they are valuable as a fertiliser to turn under. The moisture they take from the ground is worth far more to you in growing the next crop."

Chapters well worth studying are those on percolation, capillary attraction and evaporation, but can only be alluded to.

Instructions are given as to the growth of all kinds of crops and trees, and illustrations shown as to the results obtained under the Campbell system of culture. I have only space to refer to the chapter on

as most interesting to our people. "Mr. Campbell states when the farmer in the winter wheat belt (ours is all winter wheat) has learned the value of summer culture, and how it will not only greatly increase the average yield, but make a failure, so far as drought is concerned an impossibility, a larger acreage will be treated."

The experience on the Pomeroy model farm, as well as many other fields in Western Kansas and Nebraska, from 1901 to 1904, are certainly evidence that our ideas, "drawn from years of experience and observation, are something more than a theory."

"They are strong evidence as to the value of this class of work, whereby the very thorough and careful preparing of the soil (as described) a fine, firm, and moist seed bed was formed. Under these conditions, 12 quarts of seed were found to be ample. The germination was quick, and the development of the roots in the favorable soil caused liberal stooling, and in 30 days after seeding the ground was nearly, or quite, covered with the wheat. The advantages of a fine, firm, seed bed are many. One-third only of the seed is necessary. The growth of the plant is much more rapid. The development of roots is much greater, so that moisture and plant food is drawn from a much larger percentage of the soil, and last, there is a condition of soil that will hold a much greater per cent. of moisture, as well as greater power of capillary attraction, enabling the supply of moisture to be kept up from below, where, by careful work, much of the rain waters are stored, that under ordinary conditions would have been lost by evaporation or run off."

"No farmer should be content to call 20 bushels of wheat a good crop. Our prairies of the semi-arid belt are capable of producing 40 and 50 bushels with the conditions nature has provided."

Mr. Campbell recommends the following implements in addition to planters, drills and harvesters required for the crop, for the treatment of a hundred acres on his plan of the high level prairies of the more arid portions of the semi-arid belt, where the soils are of the usual sandy loam formation:—One gang plough, two 14in., one four-horse disc harrow, one four-horse combination weeder, one four-horse Campbell sub-packer, one two-row cultivator and one horse cultivator.

How far this system of cultivation can be made as successful on our northern plains and the Mallee as it has been in the semi-arid portions of the United States, only a trial will prove. Some of our soils may be somewhat heavier than the soil of the western prairies, but much of it is just as free and more fertile by nature. Our conditions are so nearly akin that the lesson taught should come home to us, for if the same success can be attained, what a vista of prosperity does it open up for the future, not only for us, but for all Australia! I can but point the matter out; it must be elaborated by others wiser and more experienced than myself, but to my mind the field is promising enough for the best attention of your department to be given to it, and a thorough trial made of the system. The cost will be but small, and any trial made should pay for itself. It has been difficult to compress the information into a reasonable length, so as to clearly define the system, and of course there is nothing original in the paper. In this and my former paper I merely state what I have seen, and read and been told.

Irrigation.

THE DUTY OF WATER.

IMPORTANCE OF THE SUBJECT.

Among all the facts that need to be ascertained in connection with irrigation, the fundamental one is the duty of water, the meaning of which term is concisely put by Elwood Mead, as follows:—"The duty of water in irrigation is the area of crop which can be matured with a given volume." To the constructor of works, the investor who finds the money, and to the user of water who looks to its use for a subsistence, the true appreciation of what an allotted volume of water can do is all important. And yet vital as this question is, it is most difficult to determine, because to get a uniform result there must be uniformity in the factors, and this is impossible to obtain. Any variation in soil, crops, rainfall, temperature, seasons, alters the result. The duty for one crop differs largely from the duty for another, and one tiller may get a duty twice as high as another, because of more thorough cultivation. In soils, even in the same locality, there may be a variation of one hundred or two hundred per cent., and therefore any attempt to fix or even approximate an arbitrary duty of water from American experience will be more or less unreliable. One fact does stand out from universal experience, that the duty of water increases the longer it is used, and that the same volume may after a few years double the area it will serve. In the early stages of irrigation, in any district too much water is usually used, and only time and experience give the true duty for the locality. In Victoria there is not the same variation in either soil, temperature, rainfall, or altitude that there is in the irrigation States of America, and if a careful system of record is maintained, in time we will, no doubt, be able to arrive at a fairly correct approximation to the true duty. The principles on which the new Water Act (as it applies to irrigation) is based renders this question of the duty of water of the first importance. The higher the duty attained the greater will be the value of the water supply, the more profitable the works, the larger the area that will be supplied, and the cheaper the water to the irrigating cultivator.

HOW LITTLE DONE TO ASCERTAIN THE DUTY.

In the course of my inquiries, I found that in the greater number of places no attempts to ascertain the duty had been made; in others, I was referred to the bulletins of the Department of Agriculture, and other gentlemen kindly sent me the results of their experience. In some cases, the duty is stated at per cubic foot per second; in others the depth of water put on the land is given. The latter is the better way to put it, as it corresponds with the way rainfall is measured. In the first case, a continuous flow per second is meant, but the exact depth put on the land cannot be given unless the length of the irrigation season, also, is stated. This, in America, may vary from two months to nearly the whole year, so that an acre foot per second in the former case means but a small part of the water used in the latter. Where possible, I will state the result in inches or feet, and this will mean 3630 cubic feet for an acre inch, and 43,560 cubic feet for an acre foot. A cubic foot per second flowing for 24 hours equals two acre feet. As the length of the irrigating season in Victoria is known, and is probably for the same classes of crops, of uniform length, a comparison can be made by those desiring to make it in whichever way the duty is put. An important point to be considered is the rainfall, which has to be added to the irrigating duty in determining the amount of water used.

At the Twelfth National Irrigation Con-

gress, held in November, 1904, attended by 468 delegates though scores of valuable addresses were given, a close perusal of the records of proceedings shows that the important question of the duty of water was left almost untouched.

This shews that private irrigators have not given the matter much attention, and that where results were obtained they could not be of general application, or they would have been stated. Where information has been obtained it has been principally by the officers of the experimental stations, under the guidance of the chief (Dr. Mead).

The instances of the duty of water I am able to give will be found to differ widely, and must not be taken as the duty that will obtain here, but merely as information to lead to a careful study of the question, so that economy in the use of our waters may be practised, and the very best results obtained from their use.

INSTANCES OF DUTY OF WATER.

At Tucson, Arizona, near where the experiment station farm is situated, the rainfall averages seven inches per year, and in some years is under five inches. There is no storage, the supply from the Salt River is intermittent, and much attention has been given to irrigation investigations. The district grows alfalfa, grain, fruits and vegetables, and owing to the intermittent supply the storing of moisture in the soil is urged. Hence the demand for winter and early spring water is large, so as to get it when available, as it is not always to be obtained when the crops need it. The soil is a clayey, gravelly loam. In the growing period the maximum shade temperature is 100 deg. to 110 deg.; the mean is from 60 deg. in March to 90 deg. in July. The total water applied on the land for the whole year was 6 acre feet. The amount just previous to and during the growing season was:—Wheat sown in moist soil, 2.1 ft.; in dry soil, 2.5 ft.; potatoes, 2.4 ft.; Egyptian cotton, 5.0 ft. At Bozeman, Montana searching investigations to ascertain the duty of water were made by the experiment station under Dr. Mead's supervision. The average rainfall here is 14 to 15 inches, the fall being greatest from April to June, when the crops need it. The season is short, barely maturing in three and one half months, beets taking a month longer. Forty-six tests as to the duty of water were made in Gallatin and Bitter Root valleys, from which a number are selected. The depth of irrigation water is given, including the rainfall during the growing period :—

Crop and Soil.	Area, acres	No. of Irrigation.	Depth of Water Applied. Feet.	Yield per Acre.
Clover, clay loam	31	2	1.02	3 tons.
Grain, loam	12	2	1.98	57 bushel
Barley, loam	66	1	0 98	73 bushel
Oats, clay loam	24	1	1.53	51 bushel
Clover, clay loam	66	2	1.98	——
Alfalfa, clay loam	53	1	1.30	5 tons.
Orchard, vegetable loam	40	4	1.46	——
Oats gravelly	102	2	6.06	34 bushel
Wheat, loam	5	2	1.19	43 bushel
Sugar beet, clay loam ...	3	2	1.46	10 tons.
Orchard, gravelly loam	40	4	1.56	——

In the above cases the length of the irrigating season was 92 days. The water used in the forgoing examples was from the laterals or on individual farms. Under the canal there will be greater seepage and evaporation, and the duty will be lower.

From the Big Ditch, Yellowstone County, for 1901, the irrigation season was 110 days, the area irrigated 18,144 acres, and the average depth of water applied 2.56ft. In 1902 the season was 140 days, area irrigated 20,038 acres average depth of water supplied 3.65ft.

From the Republican Canal, Montana, the area irrigated was 4850 acres, the average depth of water supplied in 1902 was 3.08ft.

From the Hedge Canal, Montana, the area irrigated was 5420 acres, the average depth of water applied was in 1901 3.97ft., and in 1902 5.76ft. From the Wood Canal 3985 acres were watered, the depth applied being in 1901 2.41ft., and in 1902 2 49ft. From the North Gird Creek Canal 1345 acres were watered, the depth of water applied being 1.45ft. in 1901, and 3.50ft. in 1902. From Middle Creek Canal, Montana, the area irrigated for four years was about 4000 to 5000 acres, and the water applied was. first year, 2.10ft., afterwards 1.90ft., 2.34ft., 1 15ft.

CONTRACTS FOR SUPPLY OF WATER.

In America most of the water supply is owned by canal companies, who make contracts with the water users. The following are examples:—In Arizona one company sells a perpetual right for 1-3 cubic feet per second, to be used on 80 acres. This will give a depth of over 7ft. Another company, one cubic foot per second for 120 acres, or a depth of 6ft. Another agrees to supply water to a depth of 2ft., and more if needed, at the company's option only. In California the Gage Canal Company allows

one cubic foot per second to 250 acres, which gives a depth of 2.89 feet. In Colorado the law compels companies to supply water from 1st April to 1st November, and the water rights are generally for 80 acres, the volume allowed being 1.44 cubic feet per second, giving a depth of over 5ft. In Idaho, the contracts of the Phyllis canal provide for a maximum of 2ft. in depth for 50 acres; the Boise and Nampa canal sells it at per second foot, with no limitation on the area. In Montana, the Minnesota and Montana Company sells by the miners' inch, the average supplied showing a duty of about 150 acres per cubic foot per second. In Nebraska, the North Platte Irrigation and Land Company sells water rights for 1.44 cubic ft. per second, to be used on land specified by the company. The Interstate Canal agrees to supply one cubic foot per second for 50 acres for the legal season of 200 days. This will give over 7ft. of water. In New Mexico, the Pecos Irrigation Company agree to deliver one foot per acre to be taken at such times as required. In Texas, the T. C. Purdy Company contracts allow one foot per acre to be delivered in not more than five irrigations during the year. In Washington, the Yakima Irrigation Company contracts to deliver one cubic foot per second for 160 acres from 1st April to 31st October. This gives a depth of 2.65 ft. In Wyoming, the canals do not run for more than 60 days, and the companies allow 1.46ft. during that time.

DUTY IN UTAH STATE

In Utah the rainfall is light, the average for 10 years at some 50 stations in the State being 10.99 inches. The duty of water is generally low, but investigation showed there was much waste. The growth of the State, the demand for water in the cities springing up for domestic use and for power is depleting the supply, and how to increase it is the most vital public question there at present. There is no proper control, and the authority of the Mormon Church, formerly paramount, is being gradually weakened. The outlook when I was there in September last was, owing to the increasing friction between the "Saints" and the large "Gentile" population, and more especially owing to the scarcity of water, not reassuring. In the canals from the Jordan River, which irrigate some 55,000 acres, the depth of water runs from 5.75ft. to about 3in. per acre, the average for the bulk of the land being under a foot in depth. Under the Provo River canals some 4000 acres are irrigated, the season lasting 173 days; the depth allowed is about 4ft. Under the Weber River the depth applied varied from .82ft. to 5.59ft. in depth, and it is significant that the greatest value of the crop was realised where the water was put on light. Here, again, it is stated there was great waste.

DUTY IN CALIFORNIA

In this State there has been a general looseness and uncertainty both as to the rights of water and the duty of water. In parts no attempt has been made to ascertain the latter. In Honey Lake Valley the irrigation companies have no contracts in definite terms, and merely agree to furnish water "sufficient to irrigate so many acres." The officials try to distribute fairly, but it is purely guesswork, and there can be no fair division nor economical use. Brown's Valley is in Yuba county, California, in the Sierra foothills, 300ft. above sea level. The temperature is high, and the evaporation rapid. A duty of one inch per acre continuous is considered the duty for alfalfa and grass. This will be equivalent to a second feet for 40 acres—a very low duty. In Salinas Valley, Monterey City, the duty of water of one cubic foot per second varies from 270 to 1448 acres. In the southern part of the State where water is scarce, a higher duty ranges In Sweetwater, Pomona, and Ontario the duty of one foot per second is about 500 acres, while it is estimated that for all California the same duty will average about 200 acres. On the canals fed from the San Joaquin River, the duty is estimated at one cubic foot per second to 160 acres. There is an enormous percolation however and the loss of water is reckoned at one-half the flow. On the Los Angeles River, although the irrigation from it has been enormous, no attempt to fix a duty has been made Water is distributed in day and night supplies, what is called a "head" being allowed for every 10 acres of land. This head is supposed to be about 100 inches, but it varies from 50 to 150. In the Sweetwater River system, water is distributed for irrigation entirely from pipes under pressure, and is mainly used for orchards. The duty when water is plentiful runs from 12 to 18 inches per acre per annum. It is sometimes as low as four inches, but continuous and careful cultivation is carried on, and it has been found where this is done the need of the water has not been so severely felt. The water contract issued by the San Diego Land and Town Company, the owner of the water system, provides for an acre foot of water per annum for each acre of land.

LATER RETURNS.

The foregoing illustration of the duty of water has been taken from bulletins issued by experimental stations, and from the investi

gation of the irrigation branch of the Department of Agriculture. They were tabulated from two to three years ago. Last year Professor Frank Adams, of the experiment station, Berkeley, made inquiries as to the duty of water in California, and the following are some of the results ascertained:—On the Gage Canal, Riverside, records have been kept for six years, and in these, including the rainfall, which is very light, the water used has been from 2.62ft. to 2.93ft.; an average of 2.74ft. In the Imperial district, in the South of California, the average depth of water supplied was 3.59ft., but this makes no allowance for seepage or evaporation, so that the duty must have been much higher than the figures shown. At Yuma, with a light rainfall and no allowance for losses, 5 acre feet were run. On the Tule River, including rainfall, but allowing for seepage, 2.75ft. were used. Under four canals in the Santa Clara Valley, 3.09 ft. were supplied. In 1903 the data was obtained from a large number of canals in some of the Western States for the season, and it was found in Northern Colorado 3.27 ft. were used; in Wyoming, with small individual ditches, 8.52ft.; and in Nebraska 3.60 ft.

These figures may not give the true duty, as they include loss from seepage and evaporation which in some places is as high as 75 per cent. of the water supplied.

INQUIRIES BY MR. M'COLL.

Inquiries made by myself elicited the following replies:—Professor Little, of Moscow, Idaho, states the Lewiston-Clarkston Company expects the high duty of 200 acres per cubic foot per second. Professor Knapp, of Houston, Texas, replied that the duty had only been tabulated for rice, which requires about 18in. of water. Mr. M'Pherson, the superintendent of Twin Falls Land and Water Company, states they are now engaged in a thorough investigation, and hope to get tangible results this year. The Hon. Caleb Tanner, Salt Lake City, Utah, states that there the duty is put at one cubic foot per second for 63 to 70 acres of land. Professor L. G. Carpenter, Fort Collins, Colorado, replies that in a general way 18 inches of water per annum is applied to the land. Professor Gordon H. True, of Reno Nevada, writes that on 3000 acres of land 7ft. were used, and on a single ranch 6.45 feet were used on alfalfa, and on potatoes 7.43 feet. On two other ranches the duty for alfalfa was 3.5 feet. At the experiment station the experience of two seasons gave the following observations:—

Wheat, 1.73 feet; oats, 1.76 feet; corn, 2.66 feet; roots, 5.30 feet; potatoes, 3.55 feet; alfalfa, 5.6 feet.

This alfalfa was in a very loose soil, and of course, the character of the soil has much to do with the amount of water used. John E. Booth, district judge, Provo City, Utah, estimates that a second foot will irrigate from 60 to 100 acres. Professor O. L. Walier, irrigation engineer, State College, Pullman, Washington, states they are now tabulating results of the duty of water on various crops, but they are not sufficiently advanced to publish. To the great number of inquiries made, however, no definite information could be given.

DUTY DEFINED BY LAW.

The last report of the State Engineer of Wyoming, Mr. Clarence T. Johnston, recommends that to end the uncertainty in that State as to the duty of water, and the amount growers are entitled to, the law should define the volume of water that would be delivered by a continuous flow of one cubic foot per second during an irrigation season of reasonable length. He recommends that the duty of water be fixed at one cubic foot per second for 70 acres. In Canada the North-west Irrigation Act passed in 1894, fixed by regulations under it the duty of water at one cubic foot flowing constantly during the irrigation season for 100 acres. In 1898 the matter was reconsidered, and the duty was changed to one cubic foot for 150 acres.

The precipitation in the north-west territories, which includes snow as well as rain, taken over a number of years, is, at Chaplin, 2202 feet elevation, 5.5 inches; Swift Current, 2439 feet, 15.5 inches; Medicine Hat, 2161 feet, 14 inches. Calgary, 3406 feet, 15 inches; and Macleod, 3060 feet, 13.6 inches.

In the record of proceedings of the Twelfth National Irrigation Congress, there is a paper by Dr. John A. Widtsoe, director of the Utah Experiment Station, in which the following are given as reliable results obtained at the station:—On a typical western soil five inches of water produced 33 bushels of wheat per acre; ten inches, 40 bushels, 15 inches, 48 bushels; and 20 inches, 40 bushels.

He found that up to 15 inches of water the yield increased, but a further application did not increase it. Oats were similar; five inches yielded 58 bushels per acre; 10 inches the same, but more straw; 15 inches gave 76 bushels; 20 inches, 86 bushels; and 30 inches, 82 bushels. Twenty inches water gave the largest yield. Crops differ, and the right quantity of water for each has to be found. In most cases the ratio of

yield does not increase with the water used, that is, the value of the first few inches is much greater than the later.

Potatoes differed, for with this crop 7½ inches of water yielded 160 bushels, and 71 inches 315 bushels, the intermediate applications showing an increase up to 31 inches while after that the proportion grew smaller. With all crops there is a practicable limit of profitable application of water, which should be ascertained. These points are most important, but may not be dwelt on now. J. J. Vernon, Professor of Agriculture, New Mexico Agricultural College, in his paper, gave the following figures:—Alfalfa, with 11 irrigations, using 33 inches of water, yielded 21,080lb. per acre; wheat, four irrigations, using 24 inches, gave 2826lb. per acre; corn (maize), four irrigations, using 12 inches; return not yet harvested.

CONCLUSION.

This paper has been extended beyond my intention, though I have tried to abbreviate as much as possible. It must be looked upon more as suggestive than instructive, because we cannot know that any of the instances given will quite fit our conditions. The great importance of ascertaining the true duty of water for each locality and each kind of crop cannot be overestimated. With our large area of land to be supplied and the limit of our water it is only by its application being made with a full knowledge of the time to apply it, the true amount required and proper cultivation can the individual cultivator and the State realise the full benefit they should receive

Irrigation.

COST OF WATER IN AMERICA.

I beg to hand you some information on the cost of irrigation water in the United States. The whole of the charges given are from information obtained by myself from the controllers of the various irrigation districts, and not from published records. In nearly all cases the water is controlled either by co-operative companies of farmers, who have either constructed their own works or purchased them from the constructing company, as is frequently done, or are owned by water companies, who contract with the users to supply it. In some cases these companies are purely water companies; in others they are associated with the land.

At Cheyenne, J. M. Carey and Brother state the cost of a water right is from 25 to 30 dols. an acre. The amount supplied is fixed by State law. A second report from the same State gives the perpetual right as being sold at 25 dols. per acre for one cubic foot per second for 70 acres, as fixed by law.

Professor Linfield, of the Agricultural College and Experimental Farm, Bozeman, Montana, a State on the north boundary, says:—"Many canals are owned by farmers. The charges are interest and maintenance of canals, the cost rarely exceeding a dollar per acre per year. Private companies charge up to 2 dols. an acre per year."

In the Salt River Valley Water Users' Association, Arizona, the charge is 75 cents. to 1 dol. per acre per annum.

At the Barstow Irrigation Company, Texas the price per acre for all lands for a water right is 20 dols. The annual charge for all crops is 2 dols. per acre; there is no restriction on water used, but restriction is advised for the good of the farmer.

At Eaton, Colorado, the perpetual right in a ditch for early water costs 2030 dollars for 80 acres. This is for alfalfa, wheat, or grain. Late water costs 1000 dollars for the perpetual right for 20 acres of crops, such as beets, potatoes, onions, or cabbages. The assessment on these rights for maintenance, management, etc., will average about 20 dollars for right each year.

At the Chasse Nursery Company, Riverside, the irrigation is mainly confined to citrus fruits, and the cost of water runs from 6 to 35 dollars an acre per annum. No difference is made in the charge for different qualities of land or crops.

Mr. A. J. M'Cune, irrigation engineer of Denver, states that prices have a wide range. In many co-operative companies the charge is only cost of maintenance, about 50 cents. per acre, or less. Water from large canals costs 1 to 2½ dollars per acre. It is the rule now to join land and water together, so that the annual cost will include interest on original investment and maintenance for the year. Perpetual water rights run from 10 dollars to 50 dollars per acre. The maintenance charges vary from 50 cents. to 1.50 dollars per acre.

When the Water Act was before the State Legislature of Colorado, an ad valorem tax was tried to be inserted, but it did not pass. The land, if this were passed, would have been taxed according to value and productive capacity.

W. M. Wooldridge, Hinsdale, Valley Co., Montana, states that the farmers own the lands and use them co-operatively. The first cost of construction of works runs from 2 to 4 dollars per acre, and the maintenance 15 to 25 cents. per acre annually, and 60,000 acres here have been placed under canals at a cost of 4 dollars an acre and 15 cents. per annum for maintenance. The colony was founded in 1898, and the land was then valueless. The State gave it away to any who became settlers, and now it readily sells at 20 dol-

lars an acre, the result of the expenditure of four dollars per acre for water.

Mr. Caleb Tanner, State engineer, Utah, says that water there costs annually two to five dollars per acre, according to the location of the land.

Mr. B. H. M'Allister, Land Commissioner for Union Pacific Railway, Omaha, Nebraska, states that there are four classes of ditches in the land he controls—(a) Those owned by a farmer, or two or three together, who divide the cost and maintenance, operated entirely for his or their own use, (b) the ditch owned by a corporation, the water being sold each year to the user, the charge varying from one to four dollars per irrigated acre per annum; (c) the ditch owned by a corporation, from which permanent rights are sold, coupled with an annual maintenance charge. The price of water in such ditches varies from 10 to 50 dollars an acre for a permanent right, the annual charge being from 50 cents. to a dollar an acre. Another (d) is the district irrigation ditch, operated under a State district law, and under which an annual tax is levied and collected by the district, the tax being sufficient to cover operation expenses, and to provide a sinking fund for the redemption of bonds issued for construction. The cost of water is about the same as under class C, but under class D all owners of property susceptible of irrigation are compelled to pay the tax, whether they are users or not. There is no differentiation of cost for crops or quality of land. The value of the water right depends in the first instance upon its priority on the ditch, and upon the priority of the ditch on the stream or source of water supply. It may be noted that the lands of the Pacific Union Railway traverse the States of Utah, Wyoming, Nebraska, and Kansas, and are therefore subject to different State laws.

Mr. F. W. Metcalf, manager of the K.S. and Fruit Land Company, Arcadia, Oregon, says that under the Owyhee ditch 1 dol. 60 cents. is the cost per acre this year. One miners' inch per acre constant flow is the quantity allowed. Classes of land or crops are not considered, and there are no differential rates.

Mr. J. H. Barbour, Montebello, Los Angeles Company, California:—Water is not sold by the acre, but by the miners' inch, and the cost per acre comes to about 3 dol. per annum.

Mr. W. A. Wiley, manager Arkansas Valley Sugar Beet Company, Holly, Colorado, says:—Water is not sold in that district by the acre. A water right varying from ½ to 1.44 second feet per 80 acres is sold at 20 to 30 dols. per acre This is when the water is separated from the land. In the advanced methods water and land are attached to each other inseparably, and sold together; 20 to 30 dols. is a fair estimate of its value There is no different price for water for different soils or crops.

Mr. L. G. Carpenter, director, Experimental Station, Fort Collins, Colorado, is one of the most experienced men in the States. He says their schemes are mostly based on mutual enterprise. The water is controlled by corporations, the users being the stockholders. The companies make no profit, and pay no dividends. The crops are the dividends. Assessments are levied for maintenance, repairs, etc. Where companies built in the first instance, they sold out, taking their profit at the first sale. The division of water is according to the stock held, and the maintenance varies considerably, from 25 cents. to a dollar an acre.

Mr. James Stephenson, junr., engineer, Boise Idaho, says that the average price paid for water there is 1.50 dollars per acre, no difference being made for crops or qualities of land.

Mr. R. H. Forbes, director experimental station, Tucson, Arizona, states that the price for water varies from 1 dollar per acre per year to as high as 15 dollars by pumping. There is a distinction made between winter and summer water, the latter being used for late crops is lower.

Mr. A. J. Chandler, Mesa, Arizona, states that for a variable supply of water from 1 to 3 dollars per acre annually is paid. The canal companies do not contract for a constant supply, as it varies with the rise and fall of the river.

Mr. J. W. Woolf. Tempe, Arizona, says that in this valley the year is divided into two periods, summer and winter. The average price for both periods is 1.25 dollars per inch. This is not for a continuous flow: in high water, more is delivered: in scarcity, less. Where canals are co-operative, only maintenance and operations are charged.

Mr. W. H. Code, chief engineer, Yakimi, Indian Agency, Simcoe, Washington, says that water rights, or rights of way in canals or laterals, are valued at from 10 to 20 dollars per acre. Maintenance charges are 1.50 dollars per acre. No differential charges are made.

Mr. E. C. [illegible], Bozeman, Montana, says that prices are the same for all crops, but may vary under the different canals from 25 cents. to 3 dollars per acre for a dlivery of one miner's inch per acre. A miner's inch here is a stream that will flow 1½ cubic feet per minute.

Mr J. E. Booth, district judge, Provo, Utah. says that water here is mostly owned by landowners, and the charges are those for repairs and maintenance, about one dollar per acre. Water is sometimes rented and the user pays four to five dollars per acre yearly for it. No different rates are charged.

Mr. F. C. Goudy, Denver, Colorado, is president and manager of four canal companies. He says that water is sold generally by the cubic foot per second, or by the miners' inch, and 50 statutory inches of water is sufficient for 80 acres of land. In some cases where land waters readily, 50 inches will water 160 acres. A water right of 50 inches ranges in price from 800 to 2000 dollars, depending on the locality, productions, etc. This secures a perpetual water right, with an annual charge for maintenance and operations from 50 cents. to 1.50 dollars. Water is rented annually from 1.30 dollars to 2.10 dollars per statutory inch. The average annual charge in Colorado runs close to 1.75 dollars an inch where water is rented.

Mr. A, L. Fellowes, State engineer, Bismark, N. Dakota, says that in Alberta, Canada, the Canadian Pacific Railway, in selling land, adds five dollars per acre to the price if water is available for irrigation, and charges 50 cents. per acre yearly for maintenance.

Mr. O. L. Waller, Experiment Station, Pullman, Washington, says that water is charged for at so much a year, with a duty of from 100 to 160 acres. He thinks the water should be sold by measure, as there is so much waste.

Mr. Dwight B. Heard, Investment Securities, Phœnix, Arizona, states that in this State they are uniting land and water. Alfalfa land, with a supply of water, is worth 100 dollars per acre. The only limit is beneficial use.

Mr. C. N. Perry, Imperial Valley, South California, says:—"This is going to be one of the big irrigation schemes of the United States. The Government has 500,000 acres of land that can be had under the desert law for 1.25 dollars per acre, or under the homestead law for the asking, and this company is going to supply this land and 250,000 acres in Mexico with water. This comes from the Colorado River, and is plentiful and cheap.' He adds that the cost is but 50 cents. per acre foot. There are no differential rates, and users are allowed up to four acre feet a year. The enterprise was projected and is owned by the California Development Company.

Mr. Adna Dobson, State engineer, Lincoln, Nebraska, says that the law there limits the water to be supplied to one cubic foot per second to 70 acres. The price paid varies greatly, being determined by the cost of constructing and operating the works. In the cheaply-made canals the cost is as low as 1 dol. per acre per annum; on the others the cost is much more. There are no differential charges for land or crops.

Mr. S. A. Knapps, special agent, Houston, Texas, says that the irrigation there is mainly for rice. The cost for water is from 2 dols. to as high as 9 dols. per acre. The suppliers of the water charge according to the crop, taking one-fourth, so that the cost of the water differs as the return does.

Mr. C. N. Little, C.E., State University, Moscow, Idaho, says the charge is 2 dols. per acre per annum. Under the Twin Falls Company, whose works cover 270,000 acres, a water right costs 25 dols. an acre, and 10 years are allowed for payment. The land is bought from the State at 50 cents. per acre. It is under the Carey Act. If arrears gather 6 per cent. interest is charged on overdue payments.

Mr. Jas. Withycombe Agricultural College and Experiment Station, Cornwallis, Oregon, writes that under one system there 1.50 dol. per acre is charged, regardless of crop; under another system 2.50 dols. per miners' inch is charged. One half a miners' inch is estimated to supply an acre.

Mr. A. B. Crane Brookings, S. Dakota, says that 1.50 dol. per miners' inch or per acre is charged. Differential rates are not charged to any extent.

Mr. P. J. Hazen, attorney for the Turlock and Modesta Companies, Modesta, says that water is distributed according to the acreage and value of the land in the district, and the ratio each holding bears to the cash value of all the land and the cost of the works. The area of the Turlock district is 180,000 acres, valued at three million dollars; the works cost one million two hundred thousand dollars, for which bonds were issued at 5 per cent. interest; their repayment beginning at the twentieth year after issue, and continued yearly at 5 per cent. off the principal each year. The working of the whole district costs 40,000 dollars per annum, and the area irrigated to date is 40,000 acres. Irrigation was actually commenced about four years ago. The land is assessed on its value as land, and the distribution of water follows the assessment. At present the users of water pay 25 cents per acre per year for distribution of water, 35 cents for interest on bonds, and after twenty years will need to pay 35 cents per acre per year for twenty years, when the bonds will be redeemed. As there is ample water at present, no restriction is put on its use, but as the demand increases a water rate will

be put on to restrict waste. This country is very like the Tragowel Plains, and there will be a fine system here in time.

At Berkeley College, Professors Fortier Elliott Stover Adams kindly gave me information as to charges for water as follows:—At Gage Canal, Riverside the value of a water right was 200 dollars per acre, this right calling for one-fifth of a miner's inch per acre continuous flow. A miner's inch being counted as one-fiftieth of a cubic foot per second. Counting interest at 6 per cent., this is equivalent to a charge of 12 dollars per acre per year. The cost of operation and maintenance of the system in 1904 was at the rate of 6.85 dollars per acre. The total annual cost of water is therefore 18.85 dollars per acre. At Riverside Water Company, the estimated average value of a water right is137.50 dollars per acre, with one-fiftieth of a miner's inch per acre continuous flow called for, reckoning interest at 6 per cent., gives annual cost 8.25 dollars per acre. The annual charge for operations and maintenance is 8.39 dollars per acre, making the total annual cost 16.64 dollars per acre for the same amount as used under the Gage canal. At Sunnyside Canal, Yakima Valley, Washington, the charge for water right is 30 dollars per acre, each right calling for water at the rate of one cubic foot per second to each 160 acres. Reckoning interest at 6 per cent. gives 1.80 dollars. The annual cost of operations and maintenance is 1 dollar to 1.50 dollars per acre. Total cost of water per year, 2.80 to 3.30 dollars. In Modesta irrigation district the cost of water is made up of interest on bonded indebtedness and annual expense of maintenance and supervision. This is charged against all land and improvements in the district (81,143 acres), including towns, although at present not over 12,000 or 13,000 are irrigated. In 1904 total tax averaged approximately 1.40 dollars per acre. This is charged whether water is used or not, and regardless of amounts used or crops irrigated. At the Turlock irrigation district, Turlock, California, the cost of water was made up as in the Modesta district. Area in district, 176,210 acres, of which not over 25,000 acres are now irrigated. In 1904 total tax averaged 0.56 dollars per acre, regardless of the amount of water used.

These figures correspond closely with those supplied by Mr. Hazen, attorney for the Turlock district. The Kern County Canal and Water Company, Bakersfield, Cal., furnishes water to nearly the entire territory surrounding Bakersfield, and the charge is $37\frac{1}{2}$ cents. per acre ft. At the Bear River Canal, Ogden, Utah, in 1901 the water was sold under three classifications—(1) for farm lands; (2) for orchards exceeding five years' growth; (3) for city or town lots. For any of these classes 20 dols. per acre was charged for perpetual right, entitling the holder to water at a rate of not to exceed one cubic foot per second for each 80 acres. In addition to perpetual right, which is equivalent to 1.20 dol. per year, at 6 per cent. interest, the annual rental charged for the three classes, is 1 dol., 2.50 dols., and 3 dols. respectively, making total cost 2.20, 3.70, and 4.20 dols. At the Eastside Canal, Merced, Cal., the charge for water is 2 dols. per acre irrigated, but if not contracted for by 1st January the charge is 2.50 dols. per acre At the San Joaquin and King River Canal and Irrigation Company, Fresno, and Merced, Cal., the charges for water are—For alfalfa, 2 50 dols. per acre; for cereals and corn, 2 dols. per acre, for orchards and vineyards, 2.50 dols. per acre; for market gardens, 5 dols. per acre.

It will be observed, therefore, that there is a wide difference in the charges made for irrigation water in the United States. It must be remembered, however, that the charges quoted are made over an enormous area, equal, roughly, to about one-third of Australia, and in which both climates and altitudes differ considerably. Where the rates are low is where there is abundance of water, easily controlled, and spread on the land. In other parts the high price charged appears to be no bar to its use. The rapid extension of schemes, even in the colder northern-western States and in Canada shows how important an irrigation supply as an auxiliary is considered

Irrigation in the United States.

THE MEASUREMENT OF MATTER.

While in America I made inquiry use over the quantity they are entitled to robs others of their due. Water is the most precious factor in production, for without it all other factors have no value. An acre of irrigated land will produce, say, twice as much as two acres dependent on the natural rainfall. We are careful to see the land is measured to the inch, but take little heed that the water, which doubles its production, is fairly and equitably measured.

The ablest engineers in the United States are pursuing inquiries with the object of increasing the duty of water, and checking evaporation and seepage, for it is well known that when every effort at conservation has been exhausted, and all the water utilised, 80 or 90 per cent. of the land requiring it cannot be supplied; and when we here in Victoria have all our storages completed, our methods of measurement and distribution perfected, and utilised by all the water available, we will have enormous areas needing the life-giving fluid still remaining thirsty and profitless. Two things have to be determined; first, a unit of measurement, and second, a method of ascertaining the volume correctly. There are some localities in the United States where water is so abundant that no trouble is taken to measure it, and in almost all places this has been the case at first, but as the area to be served extends, restrictions into the methods used in the measurement of water for irrigation, and send you the results. I do not know that I can give you any very new information on the matter, and possibly your engineers may be conversant with the various methods to be named, but the paper will help to call attention to the importance of the subject, which must grow in the near future. It will also detail the methods in use in the Western States of America, though it does not appear that of late years there has been any specially valuable method introduced, and the perfect system of measurement is still to be found, for it is admitted by all engineers that the best known systems are more or less defective.

In Victoria accurate measurements of water for irrigation are not general, only rough and ready methods having been used. The day for this is, however, passing away, and the increased appreciation of the value of water will compel accuracy in measuring it. This will not apply merely to irrigation water, but to all services, and especially in cities and towns, where people are most wasteful. In all other commodities we are careful to see that they are correctly weighed or measured, ensuring fair dealing between supplier and user, but in water many people think only of their own needs, and not of their neighbors. They forget that what they are being put on, and more care used.

At Vorden Ranch, Sacremento County, no restriction is placed on the use of water or measures used, and in Louisiana and Texas, no methods of measuring water have yet been employed.

In the Turlock district, measurements are roughly made by headgates, with similar openings, the calculation being made on the cross section, but as more land is brought under water, the measuring will become more accurate.

At Cheyenne, no plan of measurement is fixed, the quantity of water used being merely guessed. In Montana, weirs are used in but few places, no accurate methods being followed.

The units of measurement now generally used are the miner's inch, the cubic foot, and the acre foot. Forty miners' inches equal a cubic foot, moving at the rate of a lineal foot per second, and 43,560 cubic feet equal an acre foot. There is a general consensus of opinion that the best method of measuring is by the Cippolette Weir. This is the invention of an Italian engineer, Cesare Cippoletti, and was introduced into Western America by Professor L. G. Car-

penter, the director of the experimental station in Colorado. Among a large number of replies to inquiries on this subject, the following are selected as the most instructive:—

Professor Fortier and his colleagues, at Berkeley, state that the standard and most satisfactory methods of measuring water for irrigation in the United States are by means of the Cipolletti and rectangular weirs. These are chiefly used for streams, of from one or two to fifteen or twenty cubic feet per second. For larger canals and streams, rating flumes are chiefly used. For small streams of water, fractions of a cubic foot per second, the miner's inch box is used. They state that while these are the best known methods and devices, their use on canals is not general, except where water has a very high value. As a rule, farmers only guess at the amount of water being used and the measurements by canal companies are often very unsatisfactory

No device for giving entirely satisfactory results under the widely varying conditions under which the farmers must receive water has yet been worked out, though there is an urgent need for one. Different forms of orifice, with or without pressure submerged or open, are used in some cases, and while none of these, as used, is as accurate as is desirable, some, notably the submerged orifice, give quite satisfactory results. The current meters used are chiefly the "Price," manufactured by W. and L. E. Gurley, of Troy, New York, and the "Lallie," by J. S. Lallie, of Denver, Colo.

Professor L. G. Carpenter Fort Collins, Colo. says, water is largely measured by weir or overfall. One commonly used is the Cippoletti or trapezoidal weir. On the large canals, and those that contain sediment, the open box forming a flume is used. It is rated, i.e., the quantity showing at different depths is determined.

Division boxes are used to a large extent. The principle of these is to divide the water into fractions in proportion to the number of shares in the canal.

James Stephenson, junr., State engineer, Idaho, states:—The methods most in use are the Cippoletti weir and rating flume. A few Ventura weirs are in use for measuring in a main line where water is used both for domestic use and irrigation.

J. N. Barstow, Montebello. Cal., says that the whole question of measuring water is in process of evolution, and chaotic at that. He measures by ordinary open weir, the weir inches being then calculable into miners' inches, the charge being made a fixed rate per miners' inch.

The State engineer of Utah says that the Cippoletti weir is universally used in that State.

W. M. Wiley, who manages a large sugar beet company at Holly, Colo., where the appliances for irrigation are said to be up-to-date, states that the Arkansas River, from which their supply comes, contains much silt. The method there is a carefully-constructed measuring weir formed of three wooden sides, placed at a point where the flow is most uniform. This weir should be rated by an electric meter at different heights. Automatic measuring weirs cannot be used because of the silt.

At Chase Nursery, Riverside, Cal., the measurements are entirely over weirs, the unit being the miners' inch under a four-inch pressure. When accurate measurements are desired they have an automatic weir register operated with a clock and float, which registers the height.

At Hinsdale, Montana, the overflow measure is used.

R. H. Forbes, Arizona Experiment Station, says:—Water in Arizona is measured by the inch, 40 inches to the cubic foot. Accurate measurement is rare, the head usually being estimated with more or less accuracy by the water masters. At Mesa and Tempe, Arizona, meters are used for main canals, where heads of water are measured out, but the weir is used to supply the laterals. These methods are not considered accurate, on account of the variations in fall of the ditch supplying the water pressure on the gate, etc.

E. C. Kinney, Bozeman, Montana, on the other hand says the measuring with a meter or a weir are quite accurate, but there are also many forms of head gates used for supplying orchard and crops

John E. Booth, Provo, Utah, says:—They have used three methods—float, meter and weir. The first is not a satisfactory or accurate way. He prefers the last over the other two. They do not use either method except for division among the users.

Frank H. Goudy, Denver, Colorado, is president and manager of four canal companies, and says:—Water is sold generally by the cubic foot per second, and in Colorado the best method of measuring water as served to the farmer is the Foote spill box. He gives a description of this, which I need not repeat, as it can be seen with a drawing in Newell's "Irrigation in the United States." page 127. The idea came from Italy, and the device appears to be an excellent one. Where this weir is not practicable, the ordinary measuring weir is used.

A. L. Fellowes, State engineer, Bismark, North Dakota, says the best method of measuring water in general practice is the Cip-

poletti weir, the pool above the weir being kept in good order, occasionally flushed, and the gauge rod being carefully looked after.

Meters are not much used except in laterals, and then but seldom. Mr. Fellowes writes highly of a device invented and patented in Australia by Messrs. Grant and Mitchell, which he says is as good as any he has seen. It is now being studied by the officers of the United States Reclamation Service, with the view of adopting it upon some of their own canals.

O. L. Waller, of the Experiment Station, Pullman, Washington, writes:—The Cippoletti weir is the best, the most accurate, and satisfactory. There are a large variety of measuring devices, but none fill the bill like this, providing the silt is well kept away from the upper side.

Clemens Herschell, civil and hydraulic engineer, of New York, writes very strongly in favor of the Venturi meter, of which there are some on the Coolgardie pipe line, West Australia. He describes it as the only practical meter for large quantities of water, 700 of them being used throughout the world. George Kent, 209 High Holborn, London, builds them for all places except North America. Mr. Herschell says he has long thought they should be used in irrigation practice if furnished with an especial register at moderate cost, suited to irrigation requirements. In America they are made by Builders' Iron Foundry, Providence, Rhode Island. Mr. Herschell asked for printed information to be sent to me, but it is not yet to hand. He refers to places where they are used, and concludes as follows:—The watchman feature of such meters would be of great value in irrigation practice, by keeping all the ditches, main and subsidiary, under constant sharp watch and control.

Dwight B. Heard, of Phœnix Arizona, says the most advanced method of measuring water is the Cippoletti Weir, used in connection with standard water register.

C. N. Perry, of the Imperial Company, a very large irrigation venture, says all water is measured to consumers by means of weirs These are of three classes. No. 1, with a submerged opening; No. 2, an opening with a free discharge; No. 3, an overflow with free discharge.

A formula is given the Zanjeros, as water bailiffs are called, with a table of multipliers, to calculate the volume passing through each opening.

Professor M'Laughlin, irrigation engineer at the experimental station, Logan, Utah, states the most advanced methods for measuring water in large streams is by the use of the current meter, and for smaller streams the trapsoidal and rectangular weirs. Meters are not used to any extent for measuring water directly to crops or orchards, weirs being used in this case. I received a large number of other replies, but those quoted cover all the information supplied.

At the experimental station, Cheyenne, Wyoming, I saw a new invention for measuring water, just patented by David Hoff, of Denver. It was made of sheet galvanised iron, in the shape of a long box, having in it on a spindle four blades of sheet iron. These were double sheets, and round the edges was rubber, fitting tight to the sides and bottom of the box, so that water could not pass. At the back of these blades was a copper float, and as the water filled in the float raised, and when a certain volume was in the box, a catch holding the blades was released, and the box emptied.

The next blade then acted, holding the water; the float sank, and then raised till the requisite volume poured in, when it was again released, and the next blade moved into position.

The device I saw was measuring water from a pump, and a small contrivance connected with the spindle on which the blades were fixed registered each revolution of the blades, and gave the total water passed through.

I tried to find the inventor in Denver, but failed to do so. Though the device of the miner's inch is in use in various States, the same term has a different value.

The second foot in California, Idaho, Nevada, Utah, equals 50 miners' inches; in Colorado, it equals 38.4 miners' inches; in Arizona and Montana, 40 miners' inches.

Under the Canadian North-west Irrigation Act, the correct measurement of water is insisted on, and all devices used must be approved by the Minister of the Interior, or some officer appointed by him, who will rate the appliance and issue a certificate authorising its use.

The same strict authority on this question must at no distant date be exercised here, and the information now forwarded may, it is hoped, be of assistance in determining the selection of the most efficient methods to be used.

Further Reports of Western America.

DIFFERENTIAL RATES FOR WATER BASED ON THE VALUE OF THE LAND SUPPLIED.

Nowhere in the Western States is the ad valorem principle applied in water charges for irrigation. Where there are differential rates they are based in some cases on the products grown, or the season when the water is supplied, or the priority of the user on the channel, or the channel on the stream. The charge for water in almost all cases is fixed by the cost of the works supplying it, and the quantity available.

When the Water Act was being passed by the Legislature of Colorado, a proposition was made to base the charge on the value of the land, but it was rejected. Nor are there many who advocate it. **A.** J. M'Cune, of Denver, irrigation engineer, does so, but out of some fifty to whom reference was made he was the only one. It is in the present Victorian Act, and its operation will no doubt be interesting to note.

RESTRICTIONS ON THE UNDUE USE OF WATER.

In all cases the tendency in initiating an irrigation scheme is to use too much water, and while water is abundant the practice injures only the user, but as the area to water extends the public suffer, so canal companies and other suppliers are now more sharply defining the amount each user can take. In some States it is defined by a State law, in other cases by a court decree, one cubic foot per second being allowed for from 70 to 100 acres.

Of late years measuring appliances are becoming more general, and locked gates are put on, severe penalties being imposed for interfering with them.

In Boise, Idaho, it is a misdemeanor to waste water. Where a man has a right for a definite quantity, and pays for it, he will use it to the full extent. Where the supply is not fixed, and paid for as obtained, the user will pay as little, and get as much, as he can. Considerable power is placed in the hands of the water masters, and unfair dealing is punished by shutting off the supply. In other cases they refuse to sell more water than they think is required by the land.

Generally all suppliers of water are getting stricter in supplying it, and they thus compel economy. It is found in all cases with less water and proper cultivation that crops are better. The undue use of water logs the land, causing alkali to come through. Generally a more intelligent appreciation of how much to use is gaining ground, to the advantage of the individual and the community.

HOW ARE FARMERS EDUCATED TO USE A MINIMUM QUANTITY?

For the past seven years this has been made a special feature by the irrigation branch of the Department of Agriculture. Through its agents it has investigated the duty of water, especially where the supply is scarce, and by bulletins, addresses by experts, and personal instruction to users, has largely increased the duty, and brought about more economical use. Each of the experiment stations is also specialising this work. In New Mexico three years ago, where over 6ft. of water was used for the season, the limit was made 2ft.; any more to be specially paid for.

The result has been better and larger crops, and no one has claimed any more water. The strict watching of adjacent users is also having its effect, and Mr. Crane, of Brookings, in reply to my query how instruction was given on this subject, laconically replied, "By neighbors' kicks." Necessity is generally bringing about better practice. Larger heads of water for short periods instead of smaller heads for long periods tends to economy.

One of the most effective means of education is through the pocket. When the duty of water for any crop is obtained, make a stiff charge for the excess used, and good results will follow to all concerned. There is no more important question for us in connection with irrigation than this, for

our limited supply of water must compel not only strict economy in use, but at a very early date further and extensive storages on all our rivers.

IRRIGATION BY NIGHT.

This is largely carried on in America, but more to economise time than to save loss by evaporation. In many places water is supplied by the hour, and it must be taken when it is available, as each man's turn comes. As a rule, day irrigation is preferred, as at night there is a good deal of waste, unless the water is put on to large checks by flooding. In Arizona and the other hot States night irrigation is more favored, as some loss by evaporation is avoided, and plants do not get "scalded out." Generally, however, where it is practised, it is to save time and not water.

IRRIGATION OF WHEAT.

This is largely practised in the central, west, and north-west States, but not so much in the south. Two to four irrigations are given, from 2ft. to 2½ft. of water being used. It is everywhere a fairly profitable crop, but in some parts, where "dry farming" is progressing, the irrigated land is going out of wheat to more valuable products, such as alfalfa and sugar beets. I am inclined to think that with the better knowledge and improved methods of cultivating the arid areas, wheat as an irrigated crop will go out of fashion, for while the yield on the dry areas is not so large, the cost of production is only one-half of what it is by irrigation, and the land can be better used for other products where water can be obtained.

THE PIG INDUSTRY IN CONJUNCTION WITH FRUIT.

This is not very extensively carried on, though in places it finds favor. In Idaho some kinds of fruit, particularly the prune, give better results by feeding to young pigs than by attempting to market it. The pigs are allowed to run in the prune orchards, and put on flesh rapidly. When the prune season is over, the pigs are fed on grain for a short time to harden the flesh. For the past two or three seasons the prune crop has been so good that this has been extensively carried on. The great food for pigs is alfalfa, both for growing and fattening, fruit, where there is a surplus, being used as an adjunct.

IRRIGATION BY SIMPLE DIVERSION FROM STREAMS ONLY.

Until about seven years ago nearly all the irrigation was effected by simple diversion from streams, without storage. But as the irrigation area extended the supply from streams, many of which ran for but three or four months, and were dry the rest of the year, proved quite inadequate, and reservoir building has been extensively going on. Under the Reclamation Act many large dams are being built. The stage has been reached when large storage reservoirs to impound flood waters are essential to progress, and many are being built and others projected.

The United States will not stop till all the water possible be saved and used, and every cultivable acre turned to account.

AGRICULTURAL LABOR IN WEST AMERICA

The supply of labor for agriculture in the west is not up to the demand, though the wages are probably the highest paid anywhere, though they vary in some States. They are of all classes, a good many American, though the white American grows more and more averse to mine or farm labor. In Nevada the main labor is Italian, Swiss, German, Chinese, with a few whites, and the pay is 35 to 40 dollars a month and board. In Montana the labor is largely local or from the Eastern States or North Europe. In summer the wages are two dollars a day and no board; in winter, 45 dollars a month, and if found, 25 to 30 dollars, 10 hours' work. In Arizona, white and Mexicans, 12 hours, 1½ dollars a day and found. In Taxas, American and Mexican, 1½ and one dollar respectively per day, and 10 hours' work. In Colorado, Mexicans, Japs, Russians for beets, 10 hours' work, wages one dollar a day to 35 dollars a month, according to experience, Americans for general farm work. At Riverside, California, general work, Americans, 1¾ dollars for 10 hours; for fruit picking, many Japs at same rate. In Nebraska, one dollar to 1¼ dollars a day, runs up to 2¼ dollars at harvest, hours, sunrise to sunset. In Oregon, white labor used; by day the pay is one to two dollars; by month, 30 to 40 and found; if not found, it is 1½ to 2½ dollars by the day, 10 hours' work. In North Dakota, 30 dollars per month, with board, to 2½ dollars a day and no board. The classes are mostly young men starting life, or tramps; hours, 6 a.m. to 7 p.m. At Phoenix, Arizona, Mexicans and Yaqui Indians used as irrigators; wages, one dollar per day and board. In the Imperial Valley, close to Mexico, the labor is white, Mexicans and Indians; wages, 1½ to 2¼ dollars a day, 10 hours' work. In Louisiana and Texas the labor is mainly colored, 12 to 20 dollars a month without board; hours, sun to sun. Where white labor is used the wages are five dollars more. The labor for beets is let out, 20 dollars per acre being paid for the care of

the beets from seeding till they are pulled. At the Yakima Indian Agency, Fort Simcoe, Washington, Indians are chiefly employed; wages, one dollar to 1½ dollars for eight hours' work. At Bozeman, Montana, all nationalities are employed; wages, two to three dollars a day, not found; hours, 5 a.m. to 9 p.m. These particulars give a general idea of the wages paid all over the Western States, and show that producers here have no advantage in that respect, as our rates are lower.

DEALING WITH INSECT PESTS.

This work is generally in charge of the Board of Horticulture in each State, acting under a State law, though in some cases the counties have control. The law is strictly kept, and very rigorous measures enforced. Ample powers are given to the inspectors to compel the law being kept, and to destroy trees affected by pests. Parasites are but little used, the main remedies being banding and spraying. No one is allowed to keep a dirty orchard to the ruin of himself and neighbors.

USE OF MANURES.

For cropping, the use of manures has not become general. The bulk of the western soils are in a virgin state, and the need of fertilisers has not yet been severely felt. for orchards and special crops, manures—mostly barnyard—are used, and in Colorado sheep manure is used for beets and potatoes. In this State, however, the general practice now to restore fertility to the soil is to put in alfalfa for three years, and then plough it under.

They say it is cheaper, and acts first-class. This is the common practice at Greeley. Rotation of crops is also closely attended to. For onions, asparagus (largely grown) and truck stuff (vegetables) manures are, of course, largely used.

RAINFALL IN THE WESTERN STATES.

With regard to the rainfall, Victoria has an advantage over these States even in its driest districts. Excepting near the mountains, none of them have over a 15in. rainfall, while many are much lower. At Carson City, Nevada, it was 9.82in.; at Salt River, Arizona, 6in.; at Barstow, Texas, 12in.; at Riverside, California, 12in.; at Hinsdale, Montana, 12in.; 5in. falling in the spring months. At Montebello, Los Angelos, California, from April to November no rain falls, from November to April 10¼in. At Mesa, Arizona, for the past three years the precipitation has been 5.78, 5.68, 6.76; at Bismark, North Dakota, 15.75 is the average for 15 years. At Pullman, Washington, about 7in. falls, all during the winter months. In Imperial Valley, where one of the greatest irrigation schemes in America is being established, the water coming from the Colorado River, only 1½in. falls. At Turlock and Modesto the average is 9 to 12 inches.

These are all annual rainfalls. In regard to rainfall, Australia as a whole has nothing to fear in comparison with Western America.

RAILWAY FREIGHTS.

These vary considerably, as there are so many companies with varied rates, and each company does not keep its own rates uniform. From Eaton, Colorado, to Denver, 61 miles, for field car load lot, the rate is 12 cents. per 100lb. Mr. A. J. Chandler, president of the Mesa Improvement Company, Mesa, Arizona, kindly supplied me with the following rates. They show that the rates vary per ton mile with the places the loads go to. For car loads in cents. per ton mile:—

	Mesa to Chicago.	Mesa to Los Angeles.
Fruit, fresh...	2.9	6.3
Fruit, dried...	2.3	5.8
Canteloupes...	0.9	0.5
Grapes	1.2	2.4
Raisins	1.0	2.0
Cereals	1.7	3.6
Wheat	—	1.6
Dairy produce... ...	2.9	6.3
Live stock	1.0	2.0
Sheep	1.4	1.5

The rates at Moscow, Idaho, were in cents. per ton mile—Wheat, 1 cent.; live stock, 2 cents.; butter, 4 cents. From Modesta to San Francisco, on car load lots the freight per ton mile is—Fruit, 2 cents.; cereals, 1 cent.; dairy produce, 1½ cents.; live stock, 1½ cents. The general opinion was that the railway companies treated producers fairly, and made good provision for perishable goods.

STOCK RAISING.

In the North-western States stock is one of the great industries. They are nearly all raised on the range, and topped up on the farm. In the winter they are brought to the valleys and fed on alfalfa hay. In the irrigation districts they are almost entirely fed on alfalfa. Montana is the great cattle, sheep and horse country. Cattle sell from 4½ to 5½ dollars per 100lb. on the hoof. Sheep, 2¼ to 2¾ dollars per head. In Colorado there is a growing tendency to bring the range sheep in and fatten on alfalfa fields and stacks. They bring from five to seven dollars per 100lb. in Chicago. In Arizona the live stock is started on grazing ranges, afterwards driven to irrigated valleys and fed. Cattle here range from scrub stock to good grades, the latter

mostly Herefords. Fat stock, 3.75 dollars to 4.50 dollars per 100lb. Both cattle and sheep are largely grown in Colorado, mostly shorthorn cattle. Steers sold for feeding purposes bring 3.50 dollars to 3.75 dollars per 100lb., weighed at place of purchase, with 1 per cent. for shrinkage. Lambs, for feeding purposes, bring four dollars to 4.50 per 100lb. At Bismark, North Dakota, grass-fed beef brings 4.25 dollars per 100lb. At Phœnix, Arizona, great quantities of cattle and hogs are raised The principal are Herefords, Durham and galloways. For dairying, Holsteins and Jerseys. Hogs are mainly Poland China. Well-matured steers on the hoof market were from 3.50 dollars to 4.25 dollars per 100lb., and hogs from four to five cents per lb. In Imperial Valley, entirely by irrigation, they raise cattle, hogs, horses and mules. Beef on the hoof is 3.75 dollars to 4.25 dollars per 100lb., hogs from four to six cents. per lb. In Texas, as a business stock-raising is scarcely known. On the rice farms they keep it to consume the waste products. In the Turlock district, California, the industry is developing rapidly under irrigation, cattle taking first place, then horses and mules, hogs and sheep. Cattle bring 3¼ cents. per lb. on foot; hogs, four to five cents.; sheep, by the head, 3½ dollars; mules and horses average from 75 to 200 dollars per head. In Utah considerable live stock is raised by irrigation, mainly dairy cows and hogs. Hogs sell at four cents. a lb.; steers, 2½ cents., sheep, 3½ cents. on the hoof. The meat in America has not the quality of ours, and I do not think it will approach Australia as a cattle and sheep raising country.

GOVERNMENT AID TO IRRIGATION.

Throughout America there is absolutely no free grants for irrigation. For all works constructed the land has to become responsible. But while no direct sums are voted for works, both the National and State Governments spend enormously in aiding the people by testing schemes and teaching them in every possible way. Every farmer in America knows that if there is any trouble on his farm he cannot cope with, whether it be with water, land, stock, crop or fruit, he can get the best advice and assistance either from the Department of Agriculture at Washington, or the State experimental farms. The farmers approach them freely, and they as freely respond.

ALKALI IN SOIL AND THE REMEDY.

I found there was a good deal of this throughout the irrigation districts, and while in some it was unavoidable, in others it was the result of careless farming. It is caused by over-watering and want of proper drainage. If the subsoil is hard clay pan it soon shows itself; if of a sandy nature, not so soon. Mr. Barstow, president of the Barstow Irrigation Co., Texas, says:—"We regard alkali as useful to the crops if the land has proper drainage." The proper draining of the land is a preventive of excess. Ordinary methods of irrigation will decrease it if there is proper drainage. The bureau of soils, and the office of experiment stations have been experimenting and demonstrating the feasibility of drainag. as a prevention and cure of the evils of alkali. Fields have been drained with tiles, open drains, or wood drains, and then flooded For flooding the ground is usually checked, and the land covered with 6 to 8 inches of water to a flooding. One tract in Utah was treated in this way for 2½ summers. It is now raising a light crop—four years after first trying to reclaim it It had been previously abandoned. Well informed inquirers believe that drainage and ordinary irrigation will reclaim alkali land. Where it is not too heavy, lucern or hardy crops may be grown on it, but no other remedy for disposing of it is suggested but the drainage and leaching the land.

THE MARKETS OF THE WEST.

The growth of population is so rapid in the States that the great bulk of production in the West finds a market either locally or to the East. The cities on the West—San Francisco, Seattle, Tacoma, Portland, Spokane—are good customers, then the great central and eastern cities, with their enormous population take immense quantities. In the mining States, the camps and towns require large supplies, and so far as production from the soil is concerned, the market is within the country itself. Its politicians are seriously discussing whether the export of cereals should not be checked. For stock, dairy stuff, grain and wool, Australia should have no need to fear the competition of the States.

THE CULTIVATION OF WHEAT.

I made inquiries as to the cost of producing wheat, both by irrigation and dry farming and the returns obtained. The following is a brief summary of the information I received:—At Twin Falls, Idaho, the cost is 10 dols. per acre; at Carson City, Nevada, the cost is 6 dols. per acre. At Bozeman, Montana, 60 bushels of wheat, worth 80 cents. per bushel, was obtained. It was said the cost of irrigated wheat was 4 dols. over dry-grown, while the yield was more than double. At Hinsdale, Montana, the cost of raising wheat is 6½ dols. per acre, and the crop brought 12 dols. per acre. In Nebraska the yield is 25 to 40 bushels, and

without irrigation 15 to 30. It pays either way. In Mesa, Arizona, all under irrigation, it costs 10 to 12 dols. to grow it; yield, 2000 to 3000 lb. per acre; price, 1.25 dols. per 100 lb. In the Imperial Valley, where there is almost no rain, the cost of raising and harvesting an acre of wheat is as follows:—Water, 1 dol.; cost of irrigating, 1.50 dol; seed wheat, .75 dol.; harvesting, 3 dols.; sacks, 1.25 dols.; a total of 7.50 dols., or £1/11/3 per acre. The cost on irrigated land depends largely on the price of the water, and runs from 5 to 12½ dols. per acre; on unirrigated land it is from 3 to 6 dols.

ALFALFA—(Lucerne).

If there is any product that the Western farmer grows enthusiastic about, it is alfalfa, and one does not wonder, when it is seen how valuable it is. For cattle, sheep, pigs, poultry, it is an almost all sufficing feed. It is said to have been introduced by the Persians under Darius to Greece about 490 B.C., it having been found in Media, from which the name Medick came.

It was grown abundantly in Spain, where it was known by the Arabic name, alfalfa. It was introduced by the Chilians into California in 1854, and from there spread over the other States. Its culture will embrace a large variety of soils and climate. The conditions most fatal to its growth being cold, wet weather, or badly drained or water-logged soils; stagnant water kills it. It does best in an open, loamy soil, but adapts itself to other soils if well provided with plant food, for it is a heavy feeder. On the sides of the Rockies it grows at an altitude of 8600ft., and flourishes also at sea level. If the soil admits of it, the roots will go down 15 or more feet, or it will thrive with roots a few inches long if it gets moisture. It grows all over the Western States, on the uplands of Colorado, the plains of Kansas, or the valleys of California, and is becoming the almost universal feed. Its properties for restoring fertility to soils sick with any other crop are well known, and considered equal to any manuring the land can be given. From all the Western States I had word in its praise, and there is no need to specialise it with any one of them. In the lower altitudes and richer soils it will cut six to eight times in the year, and yield eight to ten tons of baled hay. Higher up it will cut two or three times, yielding three to six tons. The general practice is not to pasture till the last cut is off, and then feed it for two months; the rest of the year it is cut for hay and fed to the stock. In Idaho it will feed eight sheep or two cows to the acre. One ton will feed a two or three year-old steer 60 days. At Barstow, Texas, it feeds 15 to 20 hogs to the acre. In Imperial Valley, which was in the desert region, and where cultivation depends entirely on irrigation, its growth is spreading extensively. There an acre carries 10 sheep or three head of cattle. In Oregon it is the main hay crop, and principal winter feed for all stock. Its merits are well known in Victoria, and I refer to it at length, as there is an idea that special soils and treatment are required, which is not the case. It should become here, as it is in the Western States, the backbone of agriculture.

WEEDS IN IRRIGATION CHANNELS.

These are very prevalent, and there is not any organised effort to deal with them. The farmers are often careless or lazy, and watermasters have to be strict to see the weeds are kept down. They are worst in warm water and in slow running channels. Where the water comes down cold from the mountains they do not grow so much, but in the plains they thrive, especially where the velocity is slow in the channel.

A velocity of two feet per second will check their growth, but they flourish it it be one foot to per second. But little has been done in the way of special appliances to keep them down. On the Verden Ranch, Sacramento Co., they use a long, heavy V shaped knife. It is dragged along the bottom of the ditch against the current, one team of horses on either side. This cuts the weeds loose, and they float down stream and form dams. These are then taken out by means of a derrick, rigged on a waggon and a Jackson fork. It is the ranch's own scheme. In Montebello, California, they are avoided by cementing the channels, but this is expensive, costing from 20 to 60 cents. per lineal foot, according to the size of the channel.

In Imperial Valley the ditches have to be cleaned once a year. No special appliances have been generally used, but experiments are being made with some success in the smaller ditches with a machine which has two V's with the land sides 3ft. apart, and the blades drawn together in front to a point. This is drawn by 24 horses, 12 working on each side of the bank. In South California one of the chief causes of trouble is the water moss, algae. Some canals require the constant labor of day and night men to keep it down. The question of treating the canal water with copper sulphate, as is done successfully in reservoirs, was being considered.

At Logan, Utah, several methods are being tried. The most successful is a drag made of a piece of railroad rail or other similar iron, and by means of horses on either bank dragged up and down the channel. Another, even better, in use on the Bear River Canal is to strip the ordinary disc harrow of all woodwork, loaded somewhat with weight having screens at suitable intervals to catch the loose weeds, which are removed from the canal by an attendant. This appliance is said to have been very successful. In some cases a heavy chain is used, dragged up the channel.

This question is most important, as there can be no proper economical irrigation unless the channels are kept clean.

There were other matters brought under my notice I might refer to, but the collecting of this information occupies considerable time, more than I can well spare now. At a future time I may deal with other matters

DRY FARMING.

In two previous papers I drew attention to the progress of dry farming in portions of the United States, more especially in Nebraska, Oregon, and Wyoming. The enormous extent of territory in Australia, and even in Victoria, in which the annual rainfall is less than 14 inches, and the necessity, growing in importance as time rolls on, of utilising it, renders this question of dry farming or growing crops under a light rainfall one of the greatest importance. In the United States there is an area of 300 million acres in which the conditions are similar, and for the past seven or eight years great attention has been given to its utilisation and settlement. References were made previously to the work done by Professor Campbell, of Nebraska, and Dr Cooke, of Oregon, and I have since received information as to similar work going on in Utah, which is worthy of notice. The prodigal squandering of our lands in districts with an assured rainfall has driven cultivation back to the semi-arid areas, where the hazards of farming are great, and the results uncertain. But these areas are mainly the only land available for first hand settlement, and the cost of purchasing land from private owners makes the securing of it almost prohibitive to the greater number of would-be settlers. If the country still in the hands of the Crown can, by improved methods of farming, be made to yield crops, thousands will find homes, and the production of the State enormously increase; and because I believe there are great possibilities in our semi-arid regions, I again venture to call attention to the subject of this paper.

THE STATE OF UTAH.

The area of this State is 82,190 square miles, or 52,601,600 acres, rather smaller than Victoria, which has an area of 87,884 square miles. Its rainfall varies from five to 20 inches. Nine hundred and eighty-three square miles are irrigated, and in the future it is possible several thousand miles may be added. At present, however, but 1 per cent. is watered. About 35,000 square miles are mountain land, so from 45,000 to 50,000 square miles of desert remain, the only chance of developing which is to take the natural conditions and seek to improve them.

Production in Utah has been mainly associated with irrigation, though since the seventies a little arid farming has been carried on. In Bear River City, in the country between Ogden and Bountiful, and in Cache Valley, it has been fairly successful. But south of Salt Lake City little has been done, or, it was thought, could be done in this direction. But the present available water resources are reaching their limit and without very expensive works of conservation the supply for irrigation cannot be increased. Population is growing, the irrigated areas are being divided into allotments, which do not absorb the full time and energies of settlers. Besides, they are being put to the growing of more profitable crops than grain, such as sugar beets, potatoes, fruit, vegetables, etc., and hence attention has been called to the arid farm and its possibilities.

The utilisation of all the water by immense reservoirs being built would still leave more than 90 per cent. of the State without irrigation.

DESERT RECLAMATION.

The reclamation of these deserts has been engaging the attention of the Utah experiment stations for the past 10 years, but it was not till 1901 that sysematic investigation was undertaken. The dry farming carried on was studied, and careful attention given to the rainfall and climatic conditions, resulting in the opinion being arrived at that there was every chance of arid farming being successful in many portions of the State. The officers who conducted the inquiry were Dr. John A. Widtsoe and Professor Lewis. A Merrill director and agronomist respectively of the Utah experimental station, Logan. Governor Heber

port, and recommended to the Utah Legislature the proposal it contained, that experimental farms be established throughout the State in order that the possibilities of arid farming might be thoroughly tested A bill was drafted by Dr. Widtsoe, and was passed without dissent by both Houses in 1903.

THE ARID FARM ACT.

Its main provisions were that five experimental farms were to be established, only one in any county. Seeds suitable for dry areas were to be obtained both for cropping and grazing. The experimental station was to have charge and to report to Parliament annually, and the farms were to be maintained for five years. The sum of 12,500 dols. was appropriated for the establishment of the farms and the county in which a farm was to be established had to provide a site. The two gentlemen named and Senator Whitmore, from the ninth district, were appointed to select sites, and with the characteristic activity of the Americans, commencing on the 4th April, they went through the State, and had their report ready on the 3rd June, 1903, making a thorough examination of all likely localities. They recommended the establishment of six farms of 40 acres each, in the following places:—

SITES OF FARMS.

Iron County, four miles west of Parowan, Juab County, six miles south of Nephi; San Juan County, six miles south of Monticello; Sevier County, Grass Valley, 18 miles south-east of Richfield; Tooele County 14 miles south of Grantsville; Washington County, at Enterprise, 18 miles from Modena. A local foreman was at once appointed. Field operations were supervised by Prof. Merrill, the chemical and other work by Dr. Widtsoe. Rain gauges were established, and the precipitation in inches for the first twelve months in the order of the farms as above was as follows:—13.14 11.91, 10.26, 10.58, 16.56, 11.94, or an average of 12½ inches throughout the farm counties. The soil of the several farms varies in its character, the gravel areas from 1 to 20 per cent., the sand from 50 to 75 cent., the silt from 13 to 28 per cent., and the clay from 10 to 16 per cent. The gravelly soil represented the most gravelly in the State; the most sandy was apparently pure sand, and the clay soil on the Juab farm was one of the heaviest clays found in Utah. The chemical composition of the soils varied as much as their character

THE METHODS ADOPTED.

In each case the county found the 40 acres for the farm, and cleaned the scrub or sage brush from off it. Most of the experimental work was done on the Juab and Iron county farms, each being divided into 170 plots of one-third of an acre in size. The Washington, Tooele, and San Juan farms were divided into 100 plots of one third of an acre each, and the Sevier farm into 63 plots one-half acre each Plans for the testing work in each farm were prepared, which included (1) variety tests of wheat, oats, barley, lucerne, corn, grasses, etc.; (2) depth of ploughing tests; (3) cultivation tests; (4) rate of seeding tests; (5) time of seeding tests; (6) depth of seeding tests; (7) method of seeding tests; (8) crop rotation tests; (9) fallowing tests; (10) drought-resistant quality tests of crops, such as millet, kaffir corn, sugar beets, potatoes, vetches, etc. Instructions were given to plough to a depth of 10in., but this was found difficult, and on the Washington farm the ploughing was 5in. and 6in.; on the rest it was 8in. The harrow followed the plough till the surface soil was loose and fine. In some cases it was found necessary to disc the ground before the proper tilth could be obtained, but the smoothing harrow always followed the disc. About one-half of the plots were summer fallowed during the season of 1904, kept free of weeds, and under constant cultivation to conserve the moisture for use during the season of 1905. Most of these plots were seeded during the fall of 1904, the remainder during the following spring.

THE RESULTS OBTAINED.

The results secured have been the product of but one year's precipitation, and the station workers have never maintained that with present cultural methods large yields could be secured with but one year's rainfall, but that the rainfall of two or even three years may be required to produce profitable crops. Bearing this in mind, it is not surprising better yields were not secured on some of the farms, but it is rather a surprise that the yields were so good under the existing conditions even in the best farms. The following fall wheats were tested on the various farms, but a detailed report on all was not given, as one year's test was not considered of sufficient value for guidance of farmers. It was determined to conduct the tests for a few years before officially giving results of the various varieties on each farm. In Juab and Tooele counties the variety tests of fall wheat were as follows (all wheat bushels 60lb.):—

Variety.	Juab. Bushels.		Tooele. Bushels.
Odessa...	20.5	...	10.55
Turkey	23.83	...	11.14
Red Chaff...	22.08	...	12.65
Forty-fold Gold Coin ...	22.50	...	15,20
Blue Stem	13.75	...	9.6
Kopoid	18.91	...	14.1
Pelissin	16.16	...	—
Black Don	15.00	...	—
Lofthouse	16.16	..	10 02
Richi	—	...	13.4
Egyptian	—	...	11.8
Sonora	—	...	12.8

In Iron country Lofthouse led with 9 bushels; in Sevier, Turkey with 10.8; in Washington, Fortyfold was first with 6.7. In the list were two macaroni wheats—Black Don and Pelissier—the one a Russian, the other an Algerian wheat. They were sent as spring wheats, but planted in the fall, and did well, the yields being 15.0 and 16.16 bushels respectively. The chemical and milling varieties of these wheats are being studied for future report. They are called macaroni, as their main use has been to make paste foods. They belong to the botanical species "Triticum durum," hence are known as "durum," or hard wheats. They are heavily bearded, being often mistaken for barley, and the flour makes bread darker in color, tougher and heavier than ordinary wheats. It is more nutritious also, and keeps sweet and moist for longer than ordinary bread. Planted at the Juab arid farm on 19th March, 1904, it was harvested on 28th July, and four varieties yielded as follows:—Modina, 19.83 bushels per acre; Adjini, 11.50 bushels per acre; Mohamed ben Bachir, 21.25 bushels per acre; Mideah, 20.33 bushels per acre. These are good yields, but the seed had come from an arid country, and suited arid conditions

The yields of oats were also good, the best being the Sixty Day, a Russian variety, imported by the United States Department of Agriculture a few years ago It produced in the Juab farm 36 bushels; Tooele farm, 17.25; Sevier farm, 15.31; Iron farm 8.91, and in Washington was but 3.75. Other good varieties—Giant Yellow, Black American, Badger Queen, and North-western White, all of which yielded well. The barley was from irrigated seed, and sown in three counties only, yielding in Juab 34.9 bushels to 26.8; in Iron County, 10.9 to 6.15; and Washington, 5.13. The best varieties were California, California Prolific and Success. Rye did well, yielding from 14 to 12 bushels, and is highly commended as a drought-resisting cereal. A wheat named Emmer, also called Spelz or Speltz, has special drought-resisting qualities. There is a Fall and Spring variety, the latter yielding on Juab farm 23.55, and Tooele farm 17.68 bushels per acre. It is a stock feed, specially good for milking cows. The hulls cling to the grain after threshing, making it less dangerous than ordinary wheat. It weighs 28lb. to 40lb. per bushel, and is reported as "producing a fair crop under almost any condition of soil and climate, but thrives best in a dry prairie region, with hot summers, where it gives excellent yields." Lucerne planted in the fall failed, but where spring planted a good stand was obtained. It was mown at a height of eight inches to develop the roots, and prevent the moisture leaving the ground through the leaves. Next year, it was thought, a good crop was assured. Sugar beets were tried, and grew from 2lb. to 2¾lb. in weight. Grasses, corn, vetches, rye and millet were also grown with satisfactory results.

THE RESULTS EXHIBITED

All the farms sent exhibits to the State Fair at Salt Lake City, and they created much interest, being a revelation to the visitors, who could scarcely believe that in one year the sage-brush desert on which the exhibits were grown could be changed to such a fruitful field. "It marked," the papers wrote, "a new era in the farming of arid lands."

DRY FARMING ELSEWHERE.

Twenty years ago the school class books in Oregon taught that cereals (wheat, oats and barley) would not grow in Eastern Oregon, and all the country was fit for was stock. Gradually new methods of farming have been introduced, and whereas in the early days they might get a crop, but a poor one, once in three years, now they plough deep, keep the land cultivated, and get one good crop every other year, rain or no rain during the summer, harvesting 30 to 75 bushels, according to the soil and season.

Portland, the export city of Oregon, is now one of the large export cities for wheat in the States. Much of the progress here is due to the example and teaching of Dr. V. T. Cooke, of whom I have previously written. For the past two years he has been preaching dry farming in Wyoming, and is there at present on the same mission, and by recent advice from him I learn the system is making good progress. Macaroni wheats are being largely used.

THE OPINIONS OF EXPERTS.

Frederick V. Coville, the chief botanist of the United States Department of Agriculture, says that in the strictly arid regions there are many millions of acres now

considered worthless for agriculture which are as certain to be settled in small farms as were the lands of Illinois, and this without irrigation. This applies particularly to the great plateau in the Northern Rocky Mountain region.

Mr. Coville says:—"I would confidently predict that the transformation of these barren looking lands into farms through the introduction of desert plants will be as extensive a work as the enormous reclamation through irrigation."

Mr. David G. Fairchild, who is in charge of the "section of introduction of new seeds and plants," says:—"The greatest surprise to the agriculturist will come through the cultivation of what are now considered desert lands for the growing of special arid land crops, requiring but a fraction of the moisture necessary for the production of the ordinary plants of the eastern half of the United States, such as corn and wheat. We are finding new plants from the far table lands of Turkestan and the steppes of Russia and Siberia, which grow luxuriantly under such conditions of aridity, that the crops of the Mississippi Valley farmer would wither and die as though scorched by the Sirocco."

Mr. M. A. Carlton, the Macaroni wheat specialist of the Bureau of Plant Industry, says:—"The Macaroni wheat belt extends on an average the width of the United States. The Macaroni wheat country would include a very large fraction of a million square miles. Our people are but beginning to realise dimly the utterly vast agricultural wealth which lies latent in this enormous area."

Dr. Widtsoe, writing on the "Principles of Arid Farming," states:—"It is important to know the relation of the plant to the soil, and the method by which the plant obtains its moisture. Water is held in the soil in three different forms, viz., free, capillary, and hygroscopic. The capillary is the direct source of supply to the plants. It is held as a distinct film round the soil grains. Fining and pulverising the soil renders it possible for more capillary water to be held. Ploughing the land the land has a very appreciable influence on the amount of water that can be held by the soil,, especially ploughing land in the fall. The difference in the moisture that can be held in the soil as between fall and spring ploughing is over 7 per cent. The general practice is to plough to 8in. or 10in., and subsoiling is followed, at least, about once in three years. Deep ploughing increases the moisture-holding capacity of the soil, retains the water that falls on it, and draws moisture also from the deeper layers by capillary attraction.

The land generally is left fallowed every other season. Green manuring is also advocated, rye, vetch, or clover being named. From one-half to a bushel of seed is used per acre. Success in arid farms seems to be attained by deep cultivation, the retention of all moisture in the soil, and the preventive of evaporation by fine tillage, a good seed bed and good root bed and all the moisture stored to come by capillary attraction when needed for the plant. In arid Utah 1lb. of dry plant substance requires about 750lb. of water. One bushel of wheat requires approximately 50 tons of water. If the rainfall is 12in., each acre receives over 1250 tons of water—two and one half times as much as is needed for 10 bushels of wheat. If the ground is cropped every other year, and it is kept in proper condition, there will be two years' rains in the soil, less evaporation; or enough to grow 25 bushels of wheat. In the drier part of Victoria, the extreme north-west, the lowest amount of precipitation is 11.33 inches. For all the Mallee the amount of rainfall is about 14 inches. For all Victoria the precipitation averages over 22 inches. Why have we droughts and failures? Because we do not use the rainfall as we should. I believe that great as the benefits are that will ensue from irrigation, those from dry farming will far surpass them. We have 20 million acres of land in Northern Victoria, and few really bad acres in it. We have 50 million acres in Riverina of a similar character. With proper treatment and seeds the potentialities of this area are enormous, even without irrigation; with it they may be doubled. We are quarrelling like children over trifles, with all this great area to subdue, this great wealth to realise, this great country to settle. We have made many conquests, but the greatest of all, the conquest of arid Australia, still remains to be accomplished, for conquest means not only possession, but utilisation.

Probably 85 per cent. of the population of Australia is within 100 miles of the coast line. Our surplus resources of land, minerals and water need developing, for the building of homes and rearing a race. To do this the physical conditions must be studied. The man who shows that he can successfully grow crops under a 12 inch rainfall is doing more for Australia than all the politicians. The success of dry farming will solve many difficult problems.

These notes are sent out with the hope it will be tried, and if it succeeds, as it has elsewhere, then the future prosperity of Australia is assured.